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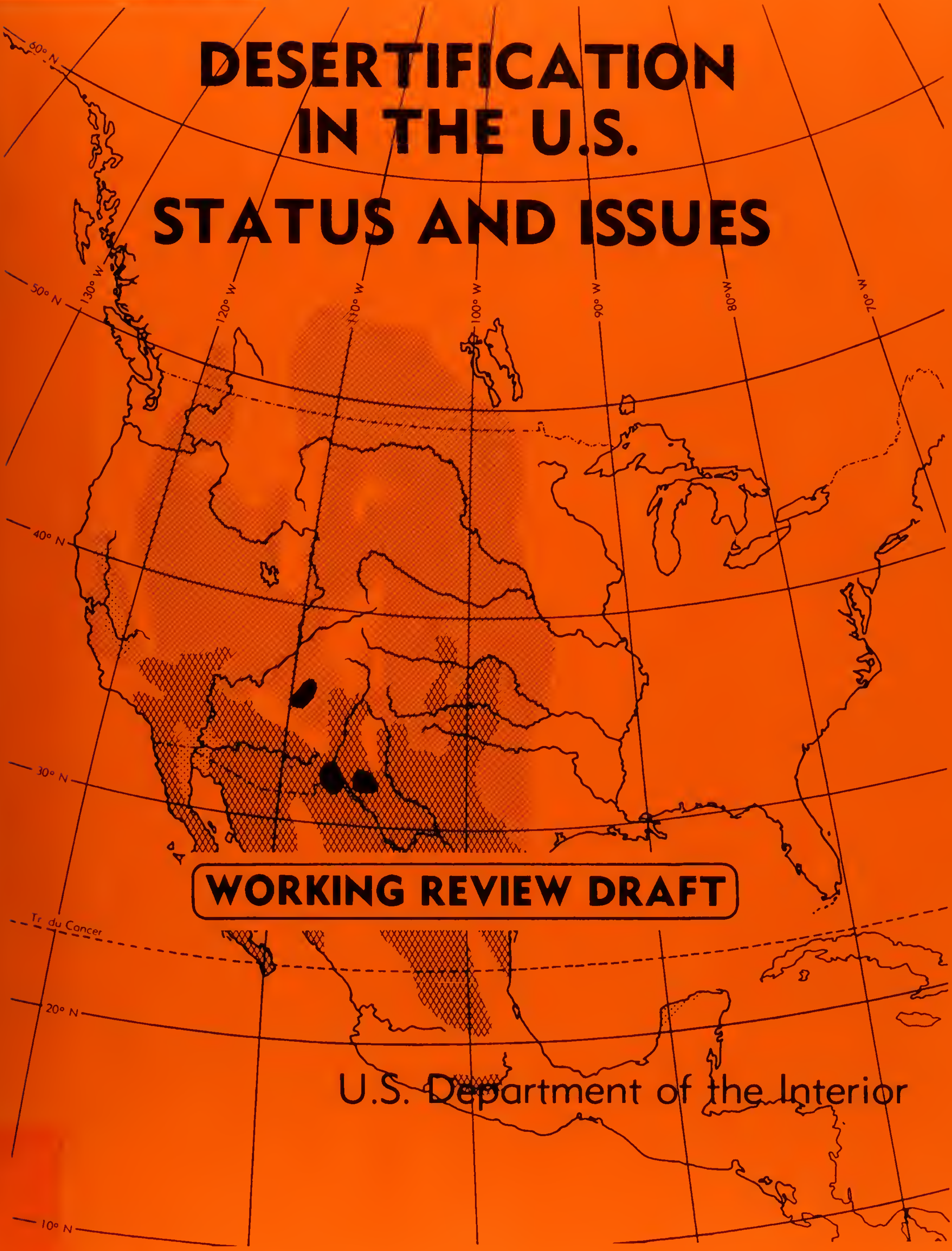
DESERTIFICATION IN THE U.S.

STATUS AND ISSUES



WORKING REVIEW DRAFT

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BUREAU OF LAND MANAGEMENT
WASHINGTON, D.C. 20240

Dear Reviewers:

The first working draft of a study entitled, "Desertification in the United States: Status and Issues," is enclosed for your review. Since this draft is designed to provide a framework for additional or improved information on the subject to be incorporated in future drafts, your thoughtful comments and suggestions will be appreciated.

This draft is an assessment of the extent, causes, and effects of desertification as presently understood. It also addresses the types of research most apt to contribute to the arrest, reversal, and prevention of the degradation of arid and semiarid lands of the Great Plains and Western States.

The first opportunity to obtain informed contributions to the draft will occur at regional workshops scheduled for August 1980 at four Western U.S. locations. The agenda and the locations of the workshops are included in an enclosure accompanying this letter. We strongly urge you to participate in a workshop, attending the one most convenient for you. In any case, we will appreciate receiving written comments no later than August 30, 1980.

The diverse contributions will be assessed and integrated through an editorial process which includes an Intergovernmental Task Force, and an Executive Steering Group representing state, regional, and national interests, of both public and private sectors. Of particular importance is the support provided by the 17 Great Plains and Western States.

Reviewers have been selected on the basis of knowledge and concern for our drylands or for interest and responsibility for ensuring best natural resource management practices.

We are grateful for your help in this endeavor. Your time and effort will contribute to a better evaluation of the dimensions of this important subject.

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Please send your reviews to me at:

Department of the Interior
Bureau of Land Management - 200A
Washington, D. C. 20240

Cordially,

Sabadell

J. Eleonora Sabadell
Program Director
Desertification Assessment
in the U.S.

Acknowledgment

The Desertification Assessment in the U.S. (DAUS) program is very grateful to the people and institutions that have guided the development of this first working draft, "Desertification in the U.S.: Status and Issues," through contributions representing local, State, and national views, interests, knowledge and concerns of the public and private sectors.

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Mr. Malcolm Baldwin	U.S. Council of Environmental Quality
Mr. Russell Brown	U.S. Senate Committee on Energy and Natural Resources
Dr. Audrey Buyrn	Office of Technology Assessment U.S. Congress
Dr. Priscilla C. Grew	California Dept. of Conservation
Mr. John Houghton	Office of Science and Technology Policy Executive Office of the President
Mr. George Lea	Bureau of Land Management U.S. Department of the Interior
Mr. Bill Long	Department of State
Mr. Frank Thomas	U.S. Water Resources Council
Dr. Priscilla Reining	American Association for the Advancement of Science
Dr. Theodore M. Schad	National Academy of Sciences
Mr. William Shafer	Consultant U.S. House of Representatives
Dr. David Herrick	Forest Service/USDA

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Member	Representing
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Mr. Cristobal P. Aldrete	Southwest Border Regional Commission/U.S. DOC
Mr. F. Kenneth Baskette, Jr.	Four Corners Regional Commission/U.S. DOC
Mr. Richard Bechtel	Western Governors' Policy Office
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Mr. Don Pendleton	Soil Conservation Service/USDA
Mr. Herbert Quinn	Fish and Wildlife Service/USDI
Mr. Jack E. Schmautz	Society for Range Management
Mr. Patrick Vaughan	Pacific Northwest Regional Comm./U.S. DOC

Guidelines for Reviewing the Working Draft,

"Desertification in the U.S.: Status and Issues"

Here are some guidelines for reviewing. By following this suggested format you will facilitate the organization of input into the second draft.

- Comments should concern the pertinence and substance of the material presented.
- When adding or revising textual or tabular data, give the complete reference of your source of information, including page number if possible.
- Preface your comments by stating the draft's section, subsection, and page on which you are commenting.

Your help is greatly appreciated, and your time and effort in reviewing this draft material will be pivotal in achieving the high quality document we are striving for.

Workshops on "Desertification in the U.S.: Status and Issues"

--- AGENDA ---

(Locations and participating States are specified elsewhere.)

At each location the two-day meeting will have the same format and cover the same agenda.

First Day: A plenary (first) session at which a general description of the draft, objectives of the workshop, and key issues will be presented. Comments from the floor will be heard during the rest of the morning.

During the second session (afternoon) of the first day, workshop groups will consider the key questions outlined and any other issue identified during the first session.

Second Day: Work groups will continue their separate discussions during the third (morning) session. The work groups will come together and report their findings in the fourth session (afternoon; plenary). Where possible a consensus of views will be presented and remaining issues and alternatives will be prepared where necessary.

Purpose: These four workshops are specifically designed to:

- Review the first working draft of the document, "Desertification in the U.S.: Status and Issues," regarding the substance and pertinence of the material presented.
- Answer the following questions, utilizing the draft as a framework:
    a) What is the extent of desertification now occurring in the Great Plains and Western States, and how intense is it? Where does it warrant special attention?

    b) What measures are currently used to prevent, arrest, or reverse desertification?

    c) Is the available knowledge sufficient for efficiently coping with the problem?

    d) What is the economic impact of desertification, if any?

    e) What are the costs/benefits of preventing and arresting desertification?
- Derive conclusions and describe other issues not covered in the draft, if necessary.

Groups and Individuals Participating

- State Government Representatives
- Intergovernmental Task Force and Executive Steering Group
- National professional and trade associations
- Associations of State Governments
- Private consultants
- Federal agencies
- Commercial, industrial and agricultural organizations
- Environmental organizations
- National conservation organizations
- The scientific community
- Professional societies

General Structures of the Workshops

Four identical workshops will be conducted:

Location	Dates	Participating States
Billings, Montana Northern Hotel 1st Avenue & 28th Street Billings, MT 59101 (406) 245-5121	August 11-12, 1980	Montana North Dakota South Dakota Nebraska Wyoming
Boise, Idaho Owyhee Plaza Hotel 1109 Main Street Boise, ID 83702 (208) 343-4611	August 14-15, 1980	Idaho Washington Oregon California
Albuquerque, New Mexico Albuquerque Inn/Convention Center 2nd Street & Marquette Ave. N.W. Albuquerque, NM 87103 (505) 247-3344	August 18-19, 1980	Texas New Mexico Arizona Oklahoma

Denver, Colorado Judiciary Chambers (Meeting room numbers will be posted.)	August 21-22, 1980	Kansas Colorado Utah Nevada

Hotels convenient to the meeting place are:

Radisson Hotel (303) 861-2000	Plaza Cosmopolitan Hotel (303) 861-9000	Denver Marina Hotel (303) 292-9010

Workshops Agenda

8:30 - 9:00 a.m. - Registration

(1) Plenary Session

9:00 a.m. - Opening remarks

9:30 - 10:15 - Overview

10:15 - 10:30 - Break

10:30 - 12:30 p.m. - Discussion and comments

12:30 p.m. - Lunch (on your own)

(2) Workshop Session

1:30 - 2:00 p.m. - Divide participants into groups (the number of groups depends on attendance)

2:00 - 4:30 p.m. - Each group will:
- Organize: select a chairman and secretary
- Review key issues and problems identified in previous sessions
- Formulate initial conclusions or approaches to identified issues and problems

(3) Workshop Session

8:30 a.m. - 12:30 p.m.
- All participants recovene as a group to consider the findings of each work group and "fine tune" issues
- Work groups reconvene to formulate recommendations on key issues

12:30 p.m. - Lunch (on your own)

(4) Plenary Session

1:30 - 4:30 p.m. - Report on findings
- Identification of issues or problems for which there appear to be a consensus on approach or resolution
- Identification of issues or problems for which consensus on approach or resolution was not reached
- Formulation of follow-up activities in response to input

4:30 p.m. - Adjourn

Please plan on making your own hotel and meal arrangements. Fill in and send in the enclosed registration form as soon as possible.

Please complete and return immediately.

REGISTRATION FORM

August 1980 Workshops

U.S. Desertification Assessment: Status and Issues

Your Name ______________________________ Phone (___)________

Address ____

____

____

☐ YES, I will attend the workshop checked below.

☐ NO, I cannot attend any workshop.

☐ I cannot attend, but this person will attend in my place:

Name ______________________________ Phone (___)________

Address ____

____

____

Workshop to be attended:
☐ Billings, MT - August 11-12, 1980
☐ Boise, ID - August 14-15, 1980
☐ Albuquerque, NM - August 18-19, 1980
☐ Denver, CO - August 21-22, 1980

Note: Please plan to make hotel and meal arrangements on your own.

Please remove this page, place stamp on other side, fold, staple, and mail this pre-addressed form back to us. Thank you.

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Mail Code 200A
Bureau of Land Management
Department of the Interior
Washington, D.C. 20240

DESERTIFICATION

IN THE U.S.:

STATUS AND ISSUES

Working Review Draft

U.S. Department of the Interior

June 1980

"The overriding influence that shapes the West is the desert. That is its one unifying force. It permeates the plains, climbs to all but the highest mountain peaks, dwells continually in the valleys. . . The desert is the guest that came to dinner, never to go away. It has stripped the mountains of their vegetation, making them "rocky"; it has dried up the inland seas, . . . For a million years a fire of low intensity has been burning, and it is still burning in the West. It is broader and more intense in the south, narrower and somewhat cooler in the north."

--Walter Prescott Webb

". . .
Who pastures high will feed on slender fare,
Austere and tough and brief . . ."

--Wilson Clough

Desertification in the U.S.: Status and Issues

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I. Background

One-third of the total land area of the world is arid. The climate is harsh, and the difficulties of wresting a livelihood from its limited resources harsher still. And yet, although as a region it is still relatively sparsely populated, it is the homeland of 14 percent of the world's population, or 628 million people, and the number is increasing. Fifteen percent of these people inhabit the extremely arid regions.

Inhabitants of this dry domain constantly have sought ways to control and modify the environment to procure food, fiber, shelter, and amenities felt necessary for their existence. In so doing, the resource base has been manipulated, sometimes for the better, but often for the worse, as the stresses imposed have been too much for the land to withstand.

Recently, attempts have been made in gross terms to quantify the effects of desertification. The estimates are based on fragmentary and local data, are subject to differing interpretations, and certainly should be viewed as falling within a wide spread until improved data can be obtained. For example, it has been estimated that twenty million km^2 (an area twice the size of Canada) of land throughout the world is now desertified or at a high to very high risk of becoming irreversibly unproductive (IUCN, 1980). Each year, as many as 14 million acres of productive land turn into deserts (Aspen Institute, 1978).

The problem is serious and global. If the indicated rates of desertification continue for the next 20 years, one source estimates that almost one-third of the world's arable land will disappear from production at a time when the increase in world population will require one-third more food just to maintain the present nutritional standards (IUCN, 1980). Difficulties in reversing the trend already exist. Perhaps one-fourth of the world's topsoil has been lost in the last 100 years due to erosion (IUCN, 1980). Fifty percent of the world's irrigated cropland (from a total of about 500 million acres) is seriously affected by salinization and waterlogging (Aspen Institute, 1978).

As the situation worsens, the costs will certainly increase. As an example, it would cost an estimated $4 billion per year to replace the nitrogen and phosphorous nutrients lost to erosion (NRC, 1976). Globally, desertification costs nearly $16 billion annually in lost agriculture production, of which almost $7 billion can be attributed to range and pastureland deterioration (Aspen Institute, 1978).

Desertification poses a particular and immediate hardship for less developed countries. It also affects developing and developed countries. In fact, there is evidence suggesting that both injudicious expansion of production in developed countries as well as the application of inappropriate technology in underdeveloped countries, can exacerbate the desertification process. It is clear that, as a worldwide problem, desertification will require a worldwide solution. An assessment of the problem at the national and regional levels has been recognized by world and national organizations as a first priority in combating and preventing desertification. Activities toward this end have already begun in the U.S. and elsewhere. Desertification is a complex problem which will require complex solutions, the concerted efforts of many in understanding it, and the concerned support of people worldwide toward halting it.

I.1

Table I-1

The extent of desertification hazard, worldwide by bioclimatic zones, and in Australia.

Degree of desertification hazard	Arid		Semiarid		Subhumid		Australia	
	sq km	%	sq km	%	sq km	%	sq km	%
Very high	1,110,477	6.4	2,180,546	12.1	158,528	1.2	307,732	4.0
High	13,439,968	77.3	2,440,098	13.6	579,717	4.3	1,722,056	22.4
Moderate	2,105,167	12.1	12,452,272	69.4	3,172,905	23.3	3,712,213	48.3

Source: J. A. Mabbutt, Search, Vol. 9, No. 7, July 1978.

I.2

II. Introduction

The term "desertification" was first used in the late 1960s to describe the northward advance of the Sahara Desert in Algeria and Tunisia and the apparent southward extension of the Sahara in the West African Sahel region that was occurring during that decade. Although the term, which can be defined loosely as the human-induced barrenness of the land, is new to our vocabulary, the effects of desertification are not. As early as 300 B.C., a Greek writer described the erosion and ruin of once-fertile lands along the coast of Turkey. There are numerous accounts since then of famines and widespread migrations of peoples when lands forced to produce beyond their natural potential deteriorated into a condition where whey could not produce at all.

The age of the problem, unfor tunately, has not brought the wisdom of recognizing the causes and of taking the necessary steps to inhibit and reverse the desertification processes. As recently as the period of 1968 to 1973, thousands of people and animals starved as the effects of the Sahel drought in West Africa were accented by past unwise management of the land.

The magnitude of the Sahel tragedy, however, brought worldwide recognition of the increasing problem of desertification, and the United Nations called for a Conference on Desertification to be held in Nairobi in 1977. The importance of this international attention to the problem of desertification cannot be understated. One-third of the total land areas of the world are arid, making them prime targets for desertification. Ironically, these lands, the least able to withstand the effects of human impacts, are being increasingly called upon to meet the resource demands of the more densely populated areas. This creates an ecologically precarious situation. As demonstrated in the Sahel region, a natural phenomena such as drought, combined with an inadequate understanding of the natural potentials of fragile arid lands can lead to tragedy. Abusing the land starves the people. But what demands can arid lands withstand?

In hopes of filling some of the known research gaps in the knowledge about desertification, a number of special studies and workshops preceded and followed the international conference in Nairobi. The United States made major contributions to the study through provision of technical advice and active participation by a delegation led by Under Secretary of the Interior James Joseph. Out of this intensive study came a generally accepted definition of the term "desertification": the sustained decline and/or destruction of the biological productivity of arid and semiarid lands caused by man-made stresses, sometimes in conjunction with extreme natural events. Such stresses, if continued or unchecked, may lead to ecological degradation and ultimately to desert-like conditions." (A more elaborate definition will be found in Section IV.) A greater appreciation of the

II.1

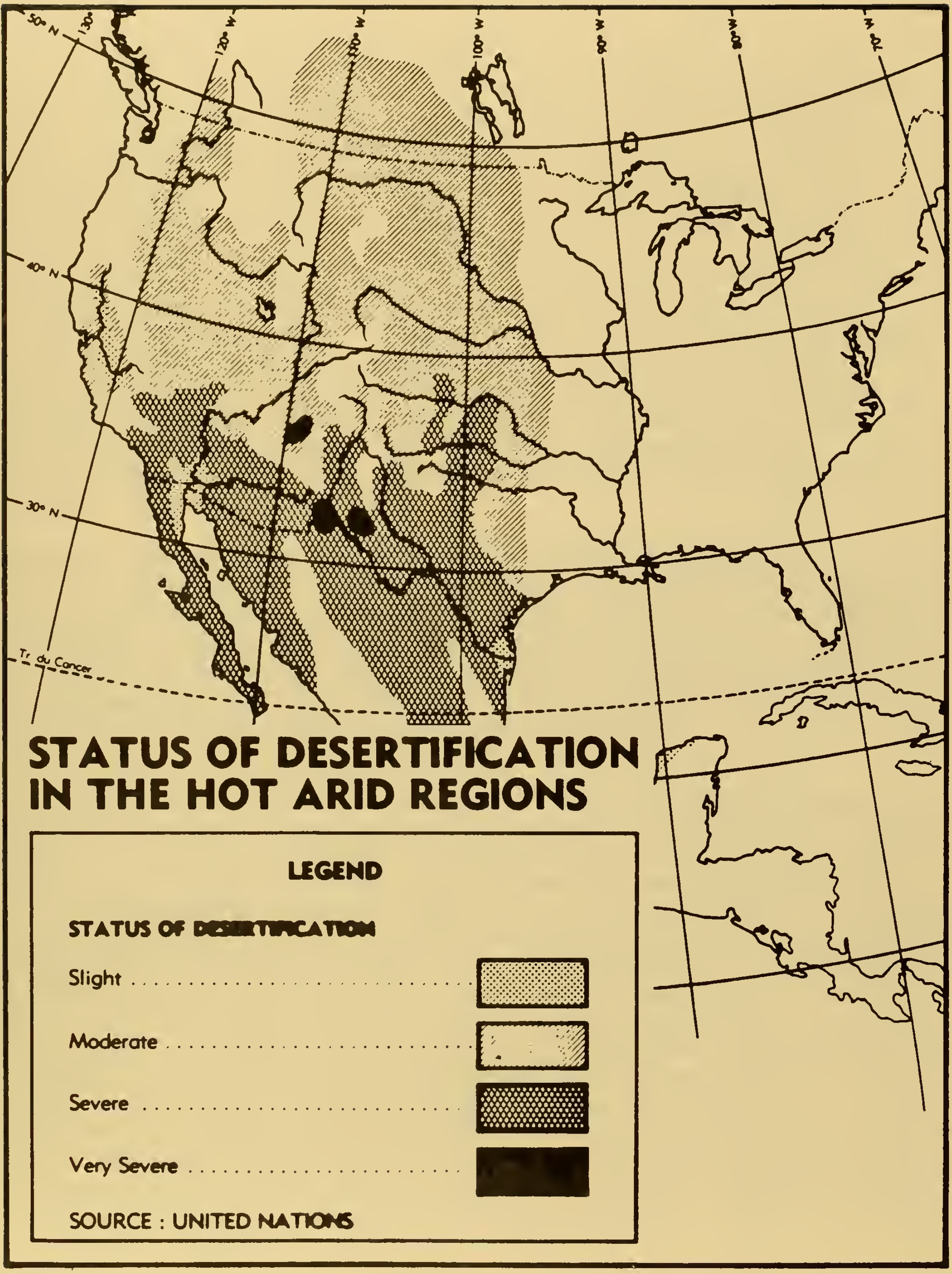
complexity of the process, and an awareness of how much further research is needed about the subject of desertification also resulted. The 96 countries represented at the Nairobi conference jointly agreed to prepare national plans of action to combat desertification, and to share the results of their individual research.

United States policy supports international efforts to deal with the effects of desertification in both the near and long terms and in different geographical and social settings. Increasingly the stability of governments is seen to depend not only on immediate relief efforts when food supplies run out, but also on fostering sound land use policies to promote food self-sufficiency. The global supply and demand in food helps determine acreages put in cultivation in the marginal, frequently semiarid, lands of the U.S.

In agreeing to a national assessment of desertification in the U.S., some areas of comparability in physical processes at work are anticipated and steps taken to combat adverse effects, such as improved technological applications, may be identified and proposed for transfer to other countries. It is also recognized that social, economic, and political factors vary greatly between countries and that human response will be very different. As one drought expert has noted, "desertification as an environmental problem is primarily national in cause and national in effect." (Glantz, 1979).

By agreement with the Departments of State and Agriculture, and under the direction of the Under Secretary of Interior, the Department of the Interior has the responsibility for coordinating this document. Cooperation in its preparation was provided by representatives of the governments of the 17 Great Plains and Western States; federal agencies; the national Executive and Legislative branches; professional societies; agricultural and other industry associations; special interest groups; and concerned individuals in the private sector.

"Desertification in the U.S.: Status and Issues" is the assessment of desertification, both present and potential, for the arid and semiarid portions of the seventeen Western States. This draft assessment will be used, after widespread public review and comment, as the basis for formulating the final assessment of desertification in the United States.



STATUS OF DESERTIFICATION IN THE HOT ARID REGIONS

SOURCE : UNITED NATIONS

Figure II-1

III. Purpose of Assessment

Early in its history, the United States recognized the value of conserving and preserving the quality of the land and on managing the land resources for the good of the nation. Examples of such legislation include the Taylor Grazing Act of 1934 and the Soil Conservation and Domestic Allotment Act of 1935. Both State and Federal Governments developed programs to preserve the land, and enacted legislation, notably the National Environmental Protection Act; the Federal Land Policy and Management Act, and the Resource Conservation Act, among others, reemphasized this philosophy and strengthened it by adding a requirement for inventorying and assessing the resource bases and interrelationships among them. These existing renewable resource management and conservation actions, however, address the problem of desertification in a limited, partial, or indirect way. The main purpose of this study is to provide an extensive and holistic overview. This study is also the first intergovernmental and multidisciplinary effort aimed at comprehensively assessing the desertification problem in the U.S. It draws heavily on available, reliable, and accepted information on desertification, to summarize it and to provide a preliminary analysis of the situation as it is found today. Through this assessment we intend to identify information and data required to adequately describe and locate present or potential desertified areas, and to draw inferences on research needs which may not have been adequately addressed.

To determine how much is known about desertification and areas requiring intensive research, this document discusses the main topics such as: the general dimensions of desertification; the component processes and what factors affect them; how desertification currently is identified, measured, and dealt with when it begins or where it is established; how we cope with the problem; and how the United States is cooperating with other countries to study the problem.

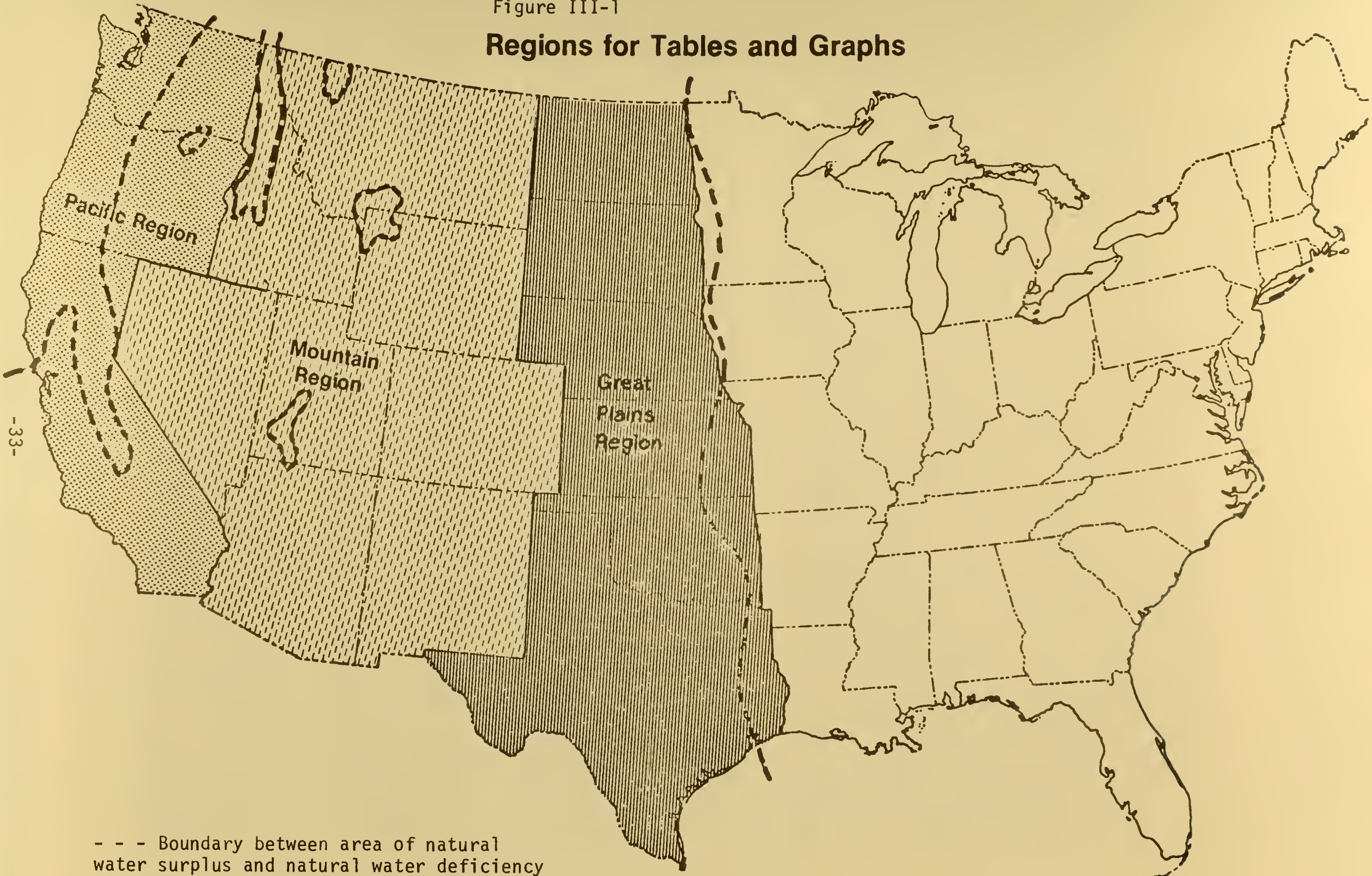
The preparation of a national assessment of desertification problems for the United States has been approached as a broadbased interagency and interdisciplinary task with particular emphasis on contributions from state and local individuals and organizations of the seventeen Western and Great Plains States. The procedure to be followed calls for close review and supervision of the project by a Task Force of senior representatives of the agencies charged with providing authoritative inputs to the assessment and by a Steering Group which members represent a wide spectrum of viewpoints, scientific knowledge and advocacy positions on proper management of U.S. arid and semiarid lands. In addition, a responsible liaison person has been appointed by the Governor of each of the seventeen Western States, who will assist in providing accurate data and in subjecting the assessment to a close review. The Department of the Interior, under the personal supervision of the Under Secretary, has established a staff within the Bureau of Land Management to perform executive functions which include preparation of drafts, conduct of interagency meetings, and appropriate coordination with interested parties to the assessment. The project has been assigned a top priority by policy levels of government and within the Department of the Interior. The schedule calls for several iterations of draft production to allow full and informed review and comment. The final draft is scheduled for release in mid-1981.

The specific focus of this assessment is on desertification induced by human activity, where the rate of change may be rapid, and where the resilience of the natural systems and the quality of the resource base is diminished or wasted. Although considerable and detailed data exist for the specific environmental elements of the resource base (soil, water, vegetation, air quality, and wildlife), the net impacts of human activity are poorly understood. As more people put greater demands on decreasing land resources, a thorough understanding of these impacts becomes increasingly important. The broad locale for this study covers arid and semiarid regions of the 17 Great Plains and Western States where annual losses of water exceed annual water gains. See figure III-1. Parts of this "dry domain" are experiencing significant growth in population and demands upon the ecosystem and there is mounting evidence that the natural qualities and productivity of some of these lands are being, or can be, degraded at an accelerated pace under the impact of increasingly intensive uses of their resources. It is here that the impacts on marginal or fragile lands are most visible and the long-term implications of human occupancy will be the most serious.

Based on the information compiled, the assessment also attempts to identify the social and economic issues involved in controlling desertification in the United States, and, thereby, to demonstrate the complexity of the problem. It is hoped that through increased awareness at all levels of the government and the public, the necessary research, analysis, transfer and application of knowledge will be supported and accomplished.

Figure III-1

Regions for Tables and Graphs



- - - Boundary between area of natural water surplus and natural water deficiency computed by subtracting value of potential evapotranspiration from the average precipitation. Source: WRC.

IV. The Desertification Process

Desertification has been defined for this national assessment as: "the sustained decline and/or destruction of the biological productivity of arid and semiarid lands caused by man-made stresses sometimes in conjunction with natural extreme events. Such stresses, if continued or unchecked, over the long term may lead to ecological degradation and ultimately to desert-like conditions." Biological productivity refers to the naturally occurring plant and animal life, as well as to the agricultural productivity, if any, of a given area. Aridity is the permanent climatic feature of regions with low average rainfall, low humidity, high climatic variations, high winds, high solar radiation incomes, extreme temperature variations, and unpredictable precipitation patterns (in time and space). In arid and semiarid lands the existing living systems have evolved mechanisms at various levels of production that allow them to survive these very harsh conditions, extreme events such as droughts, the possible dessication due to secular climatic changes, and the natural, gradual weathering of soils. The changes brought about by shifts in climate occur at such a slow rate that, even acknowledging their probability, they are of marginal concern to the present assessment.

To further clarify the concepts on which this national assessment is based, a clear distinction must be made between the natural and the man-made events that may affect an arid or semiarid region. One natural extreme event that may trigger or intensify desertification is drought. Drought is a random phenomenon and a temporary feature of the climate during which rainfall deviates appreciably below normal. Characteristically, it temporarily affects the hydrological system and the renewable resource base; it can be coped with by short-term, crisis-responsive remedial measures; and the biota, if not under other extraneous stresses, generally possess recovery mechanisms. Drought can trigger and/or intensify desertification.

Characteristics of desertification, on the other hand, are that: it is not a climatic feature; once established it may be a permanent condition; it occurs even when rainfall is above normal or when water has been made artificially available in a water-short area; it follows definite patterns; it may irreversibly affect the hydrologic system and the renewable resource base; the effects are long-lasting, and remedial and adaptive measures are in general long-term, costly, and sometimes drastic; finally, the affected biota have few or no mechanisms to recover from it.

In its inital stages desertification may merely involve a shift to a less productive ecosystem, with water, energy, and nutritional balances less favorable to plant growth than before. But land use in arid and semiarid regions affects the prevailing equilibrium. This is at least partly because of fluctuations in rainfall between dry and humid years which cannot be predicted as yet and are difficult for the land user to respond to effectively.

Deserts themselves are not the sources from which desertification springs. Except for hot winds, the deserts supply none of the essential forces for the processes described. Desertification breaks out, usually at times of drought stress, in areas of naturally vulnerable land subject to pressures of land use. These degraded patches link up to carry the process over extended areas. It is generally incorrect to envision the process as an advance of the desert borders engulfing usable land; the advancing sand dune is in fact a very special and localized case.

Desertification may occur in patches far from the constantly moving desert's limits, making the process more subtle and insidious. And because desertification may be very slow, it may not be perceived in all its development and impact. As the patchwork of desertification grows and links up, it can eventually join with the climatic desert, and the final result will look exactly as if the desert itself had spread. The deserts extended in this way form wastelands over areas that from a strictly climatic point of view should not be entirely desert. To the extent that desertification contains self-reinforcing elements, its effects may extend outward through a whole system of climatic and land-use belts. As arid pastureland turns into complete desert, neighboring semiarid land, once suitable for rainfed cropping, may deteriorate into arid pasture. But since the process does not spring from the desert cores, it need not always work outwards, and the semiarid or subhumid cropland may be the first to deteriorate to desert status.

The interrelated and self-reinforcing steps leading towards desertification follow general patterns that can be illustrated in this typical sequence of events: After human intervention (mismanaged, drastic, untimely, in conjunction with climatic stresses, etc.), the quality, variety and/or quantity of the impacted area's vegetation declines or are lost; there is a concurrent loss in the number and variety of animals that can exist in the area. With the reduction of vegetation and support for animal populations, there is a reduction in yield, and profit. A decline in yield may force land users to either further abuse the land to force it to produce temporarily at the profit level it produced before or to abandon the land for more profitable land. If the land is abandoned, then there is little chance that nature can recoup as rapidly or as successfully as it could before and without human intervention. Limited plant cover exposes the land to increased erosion , draining off the nutrients necessary for plant recovery. Once the level of topsoil is removed, the hard, often impermeable sublayers are exposed. These layers compact and develop crusts easily, which prevents water from entering the soil, thus increasing runoff, and further preventing the land from even returning to its once-productive level.

The various processes that contribute to the desertification process are examined individually in the following text.

Vegetation Loss

Induced and extensive losses of plants may result in a self-reinforcing process. As the vegetative cover is reduced or lost, the land's ability to continue with a steady production of vegetation may be impaired or even lost.

Desertification involving depletion of vegetation not only reduces the plant population and soil protection, but also alters the nutrient and hydrological cycles of the area. The amount of litter diminishes, as well as the microbiological and animal activity. The amount of nutrients returning to the cycle decreases, thus impairing the sustained normal plant growth and production.

Loss of the vegetation affects the soil quality as does the impact of raindrops. The root structure needed to conserve moisture and prevent erosion is lost. As a consequence of cover and root loss, runoff increases in velocity and volume, as do floodwaters which damage soils, plants, watersheds, property, and communities.

Another consequence of reducing the vegetative cover and baring the land is an increase in the reflectivity of solar radiation or albedo upon the land back into the atmosphere. This is considered by some climatologists to intensify desertification in semiarid/arid areas. They also suggest that the vegetative losses decrease the concentration of organic particulate in the air, and that removes nuclei on which raindrops may form, further decreasing rainfall.

Loss of Plant Variety

When the quality of an ecosystem diminishes, the plant population, and the number of varieties of perennial vegetation species, are reduced. In general, a declining ecosystem is not able to support the complexity of species it would support at the climax state. An example of this phenomenon can be found in overgrazed pasture and rangelands. The level of productivity of the land varies considerably with the biological carrying capacity of the site, the palatability of the forage produced, the way in which is it used, and the recent sequence of climatic events. When desertification by overgrazing occurs, the most palatable grasses are damaged first and then progressively less palatable species, so reducing their frequency in the community. These are the "decreasers." Not all palatable species, however, are decreasers: some may actually be encouraged by grazing use. The loss of palatable species means a loss in nutritional value of the forage and a decline in forage. In different communities decreasers are annuals, perennials, grasses, forbs, shrubs, or trees, but perennials are commonly decreasers because of their vulnerability in dry seasons and droughts when they are the only forage, and because they do not always have the same strategy of reproduction and germination as the annuals. The loss of a framework of perennials may render the system much more vulnerable in bad years when annuals fail to germinate, when the drought refuges in the shade of the large trees have gone, and when the dry unprotected soil is susceptible to erosion by wind or water.

Because their loss is likely to herald erosion at the times when they are the only protection to the soil, and because of their value as a drought reserve, a great deal of attention has been lavished on perennial grasses. It must be stated, however, that the loss of perennial shrubs and trees is also serious for similar reasons. They hold down wind velocities and so decrease both evaporation and wind erosion, and provide shelter and feed small oases in which animals and weaker plants can survive the drought to recolonize the deserts between the shrubs when the good years return or after heavy grazing is relieved.

When relieved of competition from palatable plants or plants susceptible trampling damage, resistant and usually unpalatable species expand their territory. These are the "increasers." Annuals are prominent among these, especially those with very short life cycles. In many ranges, poisonous forbs (such as the notorious burroweed of the Western United States) become dangerously common. A characteristic change is an invasion by plants from more arid neighboring regions.

When sound grazing management is applied, the species diversity may actually increase by opening up the community and creating more niches. Increased production is characteristic of the early successional stage. Resilience of communities usually increases with later successional stages. At upper levels of stocking intensity, pastures begin to degrade, sometimes drastically. It is an accepted general principle that the most valuable communities are often the first to suffer.

Brush Invasion

"For years conservation district leaders have identified brush encroachment as one of their biggest conservation problems. They point out that unwanted and undesirable woody plants reduce production of food and fiber, accelerate erosion, unnecessarily waste water, and in many places degrade wildlife habitat." (Pendleton, 1979).

Brush is defined as woody half-shrubs, shrubs, and trees that invade land on which they are not part of the potential natural (climax) plant community or occur in amounts significantly in excess of that which is natural to the site. Species listed as brush often have desirable qualities. Nevertheless, they are listed as brush because of their tendency to create resource management problems by interfering with

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intended land use and management (USDA, RCA, 1980). "The most frequent and serious woody pests mentioned were oaks, junipers, sagebrush, cactus, rabbitbrush, mesquite, and acacias." (Pendleton, 1980).

A major brush problem exists where brush is so dense that it dominates the plant community, seriously suppresses the growth of more useful plants, severely restricts land use, and leaves the soil vulnerable to erosion (USDA, RCA, 1980).

Condition: Figure IV-1 shows the four levels of the brush problem. The criteria used to rate the severity of the problem in each state include the percentage of grazing land covered by brush, the total acreage of brush, and the percentage of brush in medium and dense stands. They are as follows:

Problem Level	Criteria*
None to slight	a) Less than 26% of the grazing land is occupied by brush. b) Less than 1 million acres are in brush. c) Less than 30% of the brush is in medium and dense stands.
Moderate	a) 26 to 49% of the grazing lands is occupied by brush. b) 1 to 5 million acres are in brush. c) 30 to 49% of the brush is in medium and dense stands.
Major	a) 50 to 75% of the grazing land is occupied by brush. b) 5 to 10 million acres are in brush. c) 50 to 75% of the brush is in medium and dense stands.
Severe	a) More than 75% of the grazing land is occupied by brush. b) More than 10 million acres are in brush. c) More than 75% of the brush is in medium and dense stands.

*Applied to total state acreage.

If a state met two or more of these criteria at a certain problem level, it was rated overall at that level. If a state met all three criteria at different problem levles, it was rated as having an overall problem equivalent to the middle value. According to these criteria, three of the 17 Western States have a severe brush problem: Oklahoma, Wyoming, and Texas. Eleven of the 17 states have a major problem: Arizona, California, Colorado, Idaho, Montana, New Mexico, Oregon, Utah, Washington, Nevada, and North Dakota. Kansas has a moderate brush problem. Nebraska and South Dakota have only a slight brush problem. These ratings are on a statewide basis and do not pinpoint the severity of brush problems at specific locations (USDA, RCA, 1980) (Tables IV-1 and IV-2).

Intense pasture use can result in the invasion of woody shrubs, for many reasons. Though grasses compete with shrubs for water, the competition is not simple: shrubs can tap deeper layers and use water at different times of the year. An important factor is the suppression of burning that has sometimes been imposed arbitrarily on many ranges. On the other hand, fire can no longer be used as a management tool in some areas where grass (fuel) has been removed by grazing. This seems to be a prominent reason for the rapid spread of mesquite in the Southwestern United States and for similar brush invasion in many parts of the world. There are many other contributory factors, such as the spread of seed by cattle or rodents, or a reduction in browsing by wild or domesticated species. Whatever the reason for it, an increase in brush undoubtedly reduces grass production, and the loss of grass cover opens up the land to invasion.

This encroachment of brush and weeds can significantly reduce the productivity of range. To illustrate, the invasion of mesquite in 130 counties in West Texas reduced forage by 0.9 to 1.8 million animal-unit-months in 1971 (Osborn and Witkowski, 1974). The value of the forage thus lost was $429 million in years of below-average production and as much as $832 million in years of above-average production.

Brush management activities have been successful in reducing the overall density of the brush stand, but not in reducing the total acreage (USDA, RCA, 1980). This shift indicates that brush management activities of ranchers, farmers, and various agencies have been directed at dense stands where brush is dominant in the plant community, seriously suppresses growth of more useful plants, and severely restricts the use of land (Pendleton, 1979). Eradication is rarely a planned objective of brush management, and it is economically, ecologically, and technically infeasible (USDA, RCA, 1980). The removal of brush often may lead to as many environmental problems as the initial brush invasion. For example, removal by mechanical means such as chaining may compact the soil and disturb other vegetation as well as animals. Almost any brush removal technique, if not practiced with care and the proper safeguards, may cause accelerated soil erosion.

Loss of Animal Population

√

√ Livestock: The livestock industry is extremely important to the economies of the 17 Western States and to the nation as a whole. Desertification of the rangeland could lead, as it has, to reductions in the population of livestock, since a degraded range can support fewer animals than a healthy one.

In a survey of representative commercial cattle ranches in the Great Plains sections of Colorado and New Mexico to determine the influence of range conditions on livestock production, it was found that ranches having average good range conditions marketed 14.3 pounds of cattle per acre; those having fair condition, 11.2 pounds per acre; and those having poor condition, 8.9 pounds per acre (McCorkle and Heerwagen, 1951). Further determinations in this area would be of importance to assess actual losses in production directly tied to the lower quality of the range and pastures. (See table IV-3).

Deterioration in range condition generally reduces forage production and increases susceptibility to erosion (Branson et al., 1972). According to Soil Conservation Service estimates, nonfederal range conditions have improved considerably in recent years. They indicate that from 1963 to 1977, the percentage of range in excellent condition increased from 5 to 12 percent; the percentage of range in good condition increased from 15 to 28 percent; the percentage in fair condition increased from 40 to 42 percent; and the percentage in poor condition decreased from 40 to 18 percent. Furthermore, in 1977 range conditions were improving in 13 of the 17 major range states, remaining static in three, and declining in one. In spite of recent improvement, however, 60 percent of the non-federal rangeland is still in poor or fair condition (figure IV- 2 , table IV-3) compared to its potential measured by the resemblance of the present plant community to the original climax community (USDA, RCA, 1980). But range conditions vary greatly among states (tables IV- 4 and IV- 5).

About 453 million acres in the Western U.S. are nonfederal rangeland and native pasture. In 1976, the latest year for which data are available, about 68 percent of this acreage was reported as properly grazed, and about 32 percent was reported as overgrazed (USDA, National Resource Inventories). Rangeland productivity was estimated to be 55 to 60 percent of potential.

There were 213 million acres of federal rangeland in the 17 Western States in 1977, with 149 million acres mainly administered by the Bureau of Land Management, and 37 million acres by the Forest Service. Other federal rangeland, totaling some 42 million acres, is mainly administered by the Bureau of Indian Affairs, National Park Service, and the Department of Defense. Thirty-two percent of the Western rangeland is in federal ownership (table IV-6) and more than 70% of that is considered in poor to fair condition (table IV-). In general, however, the quality of the ranges has improved from the 1930s on, and today these lands are in the best condition found during this century.

Cattle and sheep graze on almost two-thirds of the public rangelands of the West. (They graze on about 85% of the rangelands in both public and private ownership.) The lands generally are grazed at different seasons over the year, rather than over the entire year.

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The lower elevation of grasslands and shrublands, which generally are administered by the Bureau of Land Management, are used primarily during the spring while the higher elevation grassland and meadows, generally administered by the Forest Service, are used mainly in the summer.

The sheep industry is especially dependent upon federal grazing lands which provide about 42 percent of their annual forage requirements. The cattle industry is generally less dependent upon federal land, but the relationship between the public and private land as sources of feed is often very important locally to that industry.

Wildlife existing in the seventeen Western States has been profoundly impacted through the years by changing land uses such as farming, livestocking, the building of urban areas and transportation systems; mining, recreation, and other human endeavors. Man-caused productivity losses have had specific effects on wildlife as well, but these impacts are difficult to disaggregate from the land-use-generated ones above. The difficulty in distinguishing between effects of desertification and of ecological changes due to development, is compounded by the presence of feral animals that also compete for the resource base and perturb its equilibrium.

The population density of wild horses and burros, like that of any other animals, must be in tune with and not exceed the carrying capacity of the available habitat. Other than this general observation and the limited data that Hall (1972) and Feist (1971) collected on the Pryor Mountain horses, there is no scientific information available on optimum population levels, the results of overcrowding, competition, or the effects of a degrading habitat.

Not only large animals but smaller ones are affected by desertification. Small mammals consume only a small part of an ecosystem's production, they may suppress the vegetation on which they do feed. The ecosystem vegetation type usually does not change due to the feeding of small mammals, but it may be held or maintained in one seral stage due to their feeding. Exceptions are degradations due to large populations of grasshoppers or locusts.

Decline in Yield

The desertification process on cropland occurs through land degradation by soil erosion caused by widespread removal of topsoil by wind and water, which may result from tillage and harvest practices. Increased water runoff that attends soil losses reduces water availability to crops and causes flood damage to other crops. Removal of finer soil particles leads to compaction, crusting, poor tillage, and consequent lower crop yields. Selective removal of plant nutrients and organic matter constrain farmers to resort to the use of chemical fertilizers, so as to maintain a given level of production. This in turn may result in high water salt content in irrigation return flows and runoffs, and in soil salinization. Other vegetational problems of the arid/semiarid regions that may result in or trigger desertification are:

- disease and pest invasions due to monocultural planting patterns
- loss of soil support and soil structure
- loss of seedlings due to burial and sandblasting
- land uses that eliminate native species
- loss of biological activity in soils due to declining amounts of humidity and nutrients
- poor drainage and low hydraulic conductivity that raise the water table to the plants' root system restricts or stops plant growth.

It is acknowledged that soil erosion generally diminishes crop production, but the effects are difficult to generalize because of the influence of factors such as crop variety, topsoil depth, soil nutrients, soil structure, drainage, temperature, moisture, tillage practices, weeds, and pests. Evidence suggests that corn yields, for example, are reduced annually by an average of about 4 bushels per acre for each inch of topsoil lost from a basis of 12 inches of topsoil or less; oat yields by an average of about 2.4 bushels per acre; wheat yields by an average of 1.6 bushels per acre; and soybean yields by an average of 2.6 bushels per acre (Pimentel, 1976). The primary reasons given for the reduced yields on eroded soils are low nitrogen content, impaired soil structure, deficient organic matter, and reduced availability of moisture.

Crop production in the Western States is 45% of the total U.S. production, for a cash receipt and home consumption value of around $22 billion. See tables IV-8 and IV-9 . More than $440 million are thus lost each year to erosion alone, since it has been estimated that the approximate annual crop loss due to nutrients, crop sandblasting and burial, uncovering of seed, compaction, etc., is about 2%.

Decreased yields follow from the loss of nutrients. Dregne (1978) found desertification of dry farmed lands due to erosion had reduced yields on sandy lands by 30 to 40 percent and on hardlands by 20 to 30 percent. Using a conservative figure of 25 percent decrease in yield due to desertification, there is an annual reduction of wheat yields in the semiarid West of about 300 million bushels. Assuming wheat were $3.00/bushel, this would be a $900 million loss in revenue from wheat alone. Similar reductions of grain sorghum yields will be found throughout the Great Plains states. Lyles (1975) calculated that income from wheat and grain sorghum in 13 counties in western Kansas was reduced by $2.5 million (at 1973 prices) as the result of wind erosion on sandy lands. High valued crops are not as affected by desertification since they are more intensively managed (irrigated and fertilized) and are grown on the better soils.

Erosion

Soil can be removed by wind and water. This soil removal occurs and is accelerated when the soil surface is disturbed or lain bare by clearing, ploughing, trampling, overgrazing, stripping, etc. When soil loses organic matter or dries up, erosion may further progress. (See figure IV-3.)

The lost topsoil is the most fertile. The subsoil, being poor in nitrogen and phosphorous, or heavily cemented, is hard and impermeable and is more difficult to erode.

The two main types of soil erosion are

(a) Water erosion

Damage by water is the result of three principal processes. First, the impact of the raindrops compacts the surface and crumbles the weak soil aggregates, which, when wetter, slake more readily; these processes together reduce the aggregates to smaller and more easily transported particles, which become plugged into pores in the surface to create an impermeable crust. Second, the splash itself projects the separated particles outward; and third, the particles are carried off in any runoff that occurs. The effectiveness of these processes depends largely on the intensity with which the rain comes down: More intense showers have more energy to pound th soil and splash it farther, and under intense rainfall the surface cannot absorb water fast enough to prevent runoff.

Slope angle and length, and the inherent tendency of the soil to erode also affect the amount that may be lost from a field. Sandy soils are permeable and therefore resist runoff, but when their infiltration capacity is exceeded, their poor aggregation renders them very vulnerable. In the silty soils of much of the temperate desert margins, the infiltration capacity is commonly exceeded by rainfall intensity and these soils are very liable to erosion. Clayey soils, because they have the tightest aggregation and generally occur on gentle slopes and in low spots in the landscapes, are not usually eroded. They may even benefit from sediments and nutrients washed from higher sites.

Runoff sorts the soil it picks up, moving small stones only a short distance, depositing sand usually at the first break of slope, and the more valuable silt, clay and organic matter to distant lakes, reservoirs or the sea. Reservoir siltation is a serious problem in semiarid lands: Rapid natural erosion, and even more rapid induced erosion transfer debris into the traps provided by storage reservoirs. In the Western United States there have been reductions in the storage capacities of reservoirs: New Lake Austin in western Texas lost 96 percent of its capacity in only 13 years. Siltation is not confined to the reservoirs alone: Disruption of the river regime above the huge Elephant Butte Reservoir on the Rio Grande meant that a depth of over 1 m of sediment was deposited in the river channel at Albuquerque some 160 km upstream. Below the dams there was extensive downcutting in the river channels.

Increased runoff needs a better network of streams to remove it. In an intense shower, the stream network may quite suddenly be expanded when steep-sided gullies cut back into fields. These gullies are usually discontinuous, cutting only into locally steeper slopes along river bluffs or terrace edges. Gullying removes less soil than surface runoff, but the dissection of fields that results may make cultivation impossible and more dramatic.

The 1977 National Resource Inventories (NRI) (USDA, 1978) showed that erosion is the main conservation problem on most of the West's cropland. In 1977 average annual erosion exceeded six tons per acre on croplands of the Western States. Erosion rates in 1977 were more than five tons per acre in seven states and more than ten tons per acre in three states. A ten-ton per acre annual erosion rate is the equivalent of removing one inch of topsoil every 15 years.

In tons per acre California, New Mexico, Colorado, and Texas have the most severe sheet, rill, and wind erosion problem. Of the nearly one billion tons of cropland topsoil lost each year to water and wind erosion across the Western States, only about one-fourth is balanced by the natural soil formation under normal agricultural conditions.

Water erosion is particularly acute on the steep slopes of the wheat lands in the Palouse region of the Pacific Northwest and on the shale-derived soils of the Dakotas, Wyoming, Colorado, Utah, and New Mexico. Virtually every medium-to-fine textured cultivated soil having a slope greater than 1 percent is subject to water erosion. When slopes become as steep as they are in the Palouse country, good land management can retard erosion, but can keep it within tolerable limits only with difficulty.

Erosion is also a major contributor to salt loading in Western streams. Soils high in salt content, such as marine shales, are high contributors, and probably the largest diffused source. These salts are highly soluble and are concentrated in surface runoff through erosion. Over four billion tons of soil are picked up each year by the nation's streams, and 25% of this total tonnage is discharged into the oceans. The other 75% is moved around within drainage basins. The dollar amount of damages caused by sediment is difficult to determine, but it has been estimated at over $500 million per year.

(b) Wind erosion

Like runoff, the wind picks up, transports and sorts the soil, removing nutrients and clogging nearby areas with unwanted sediment. Clay, silt, and organic matter may be removed far from the drylands altogether: Sands are moved close to the ground, blasting the remaining crop and accumulating around local bushes and hedges as small dunes with a much lower fertility and "tillability" than their parent soil. A form of veritable "desert creep" can occur on a small scale as the eroded sands blow onto, blast, dessicate, and bury crops in neighboring fields. Soil loss usually continues until it is checked by a hard or cemented subsoil. The wind erosion hazard is greatest in temperate dryland farming where the soil may be left fallow for one or two seasons.

The formation of small mounds of sand and dust around bushes is, like gullying, an inconvenience to cultivation. These mounds are partly the result of the erosion of the less protected areas between the bushes and partly due to the accumulation of moving sand and dust in the calm area around the obstruction.

Wind and water erosion combine in some areas to form further kinds of impoverished landscape. Where the soil is stony, the removal of finer material by water or wind leaves stones littered on the surface as a "desert pavement." Shallow "scalds" (yardangs) develop in which the topsoil is stripped off by both wind and water. These areas, often a few hectares in extent, have such hard surfaces that plants find it hard to recolonize without the help of ploughing and seeding (Warren, 1975).

Wind erosion occurs throughout the arid West and most of the land damage is found in the southern half of the 17 Western States. The Dust Bowl of the 1930s in the southern Great Plains typified the hazard that exists in any arid region. It was the result of a severe and protracted drought striking a region where cultivation had been extended too far into climatically marginal areas and where overgrazing had reduced vegetative cover. To a less extensive degree, wind erosion is a locally serious problem around barren mine waste dumps, recreational areas, and new and hastily built communities.

The number one wind erosion problem is the cultivation of sandy soils on the dry margin of the semiarid climatic zone, and the severity of wind erosion is dependent upon year-to-year fluctuations in weather. Approximately 4.6 million acres (1.8 million hectares) of cultivated land in the ten Great Plains states were damaged by wind erosion during the drought-parched winter of 1975-76 (October 1975 through March 1976) (Anon., 1976). This contrasts to the previous less severe winter in which 1.7 million acres (1.1 million hectares) were damaged by wind. Hagen and Woodruff (1975) calculated that particulates suspended in dust storms in the Great Plains during the 1950s and 1960s ranged from 37 to 551 million tons annually. Because of increased rainfall, the average dropped from 244 million tons in the 1950s to 77 million tons in the 1960s. Wind erosion produces a larger mass of particulates in the United States than all other primary sources combined (Dregne, 1980).

While one erosion control practice has been losing popularity, another has been gaining. Shelterbelts (windbreaks), though effective if managed properly, have become less acceptable in the 1960s and 1970s than they were in earlier years. The main reasons are that they usually occupy land that could be cropped and they interfere with the operation of center-pivot irrigation systems. On the other hand, minimum tillage and no-tillage practices have been gaining acceptability. These tillage systems keep stubble on the land to effectively protect it from wind and water erosion.

Erosion is affecting both the public and private lands of the West. Sheet and rill erosion on Western croplands average 2.9 tons per acre, and wind erosion on croplands in the Great Plains averages 3.4 tons per acre. On rangelands the average annual sheet, rill, and wind erosion in the 17 Western States is 5.28 tons per acre. Serious soil erosion has affected about 100 million acres, and moderate erosion over 210 million acres (BuRec, 1975). Erosion may also induce landslides, channel degradation, valley trenching, and floodplain scouring. See erosion information in figure IV-4 and tables IV-10 through IV-17.

Erosion also has serious adverse effects on air quality. Atmospheric dust impairs human and animal health, ruins machinery, is responsible for highway accidents, and--when dust storms are bad--causes mental depression. Sediment in streams and lakes interferes with fish reproduction and survival, reduces reservoir capacity, and makes it necessary to dredge ship channels. Realistic costs of these kinds of damage are difficult to calculate.

other uses.
Erosion also drains state revenues from/For example, in Whitman County in the Palouse region of Washington, more than $400,000 is spent annually to remove silt from the county road system. In one Texas county, officials estimated that an average of $75,000 to $100,000 was spent each year from 1972 to 1974 clearing and repairing roads and drainage ditches damaged by water and wind erosion.

More than $15 billion has been spent since the 1930s on soil conservation practices (White House, 1977) but it must be added that in fuel costs alone, an estimated 2.1 billion gallons of fuel equivalents are used each year (as of 1975) to offset soil erosion in the United States (Pimentel, 1976).

Tables IV-18, IV-19, and IV-20 show the Erosion Condition Classification on BLM Land by state (table IV-18); on state and private land by state (table IV-19); and on the total land Bureauwide, and the ten Western States (table IV-20). The acreages shown may deviate from the actual acreage due to factors such as: (1) Some small amounts of land have not yet been surveyed; and (2) States with only small amounts of BLM land are administered by other State BLM offices. Thus, North Dakota BLM land is included in the Montana total. BLM has in operation a computer-based system by which approximations are generated to forecast the increase or decrease in acreage in each of these condition classes under different types of management plans.

The system used to classify the soil condition is shown in figure IV-5 which presents the factors to be measured. This form is used to evaluate the erosion condition of parcels of land 6400 acres or less in size. While this method is adequate, though not rigorous, the classification does not reflect the loss of biological productivity of the land. For example, a "moderate" soil erosion determination, upon close examination, reveals conditions which significantly reduce the biological productivity of the area surveyed. As is is, the relationship between erosion and productivity has not been established for use in management plans. A system which reflects this relationship is needed to better portray the condition of an area as a whole.

The critical erosion problem areas of the West on cropland, rangeland, forest land, and urbanizing areas are as follows:

Crop Land: Soils are generally subjected to a continuous process of erosion by the action of rain, melting snow, ice, frost, and driving winds, especially where continuously lain bare by cultivation.

Water erosion is especially serious in the winter wheatland area of the Columbia Plateau in eastern Washington and Oregon and northwest Idaho. This includes the Palouse area. Most of the cropped area is covered with loose soil which is fine-grained, unstable, windblown material on slopes up to 50 percent. Here the soil profile frequently is saturated and freezes before a snow cover occurs, and so becomes a supersaturated layer of soil which erodes during the late winter or early spring runoff. Soil losses with these conditions can be 25 to 150 tons per acre.

Within the arid regions, the economic feasibility of controlling wind and water erosion decreases as the climate becomes drier. In the wet fringes of the semiarid zone (east of the 100th meridian), control of water erosion (a major problem) on cultivated land is much more likely to return a profit in five to ten years than is water or wind erosion control on the drier side of that zone. The reason is not only that land productivity is higher in the wetter areas but that water erosion is easier to control than wind erosion. Residue management is one of the best tools for wind erosion but there can be little management if there is little residue.

Another point to note concerning the economics of wind erosion control is that droughts exacerbate the problem. One year of severe drought seldom has any great effect on farmers but two or three consecutive years can be disastrous. By that time, there will be little crop residue to hold down the soil, soil structure will have degraded, and emergency tillage will have become ineffective, all of which contribute to an increased susceptibility to erosion.

On the dryland sandy soils that blow easily, there is only one way presently known to control wind erosion: establish a permanent vegetative cover. Since a cash crop usually will be more profitable than livestock raising on such soils, farmers are not likely to invest money in retiring land from cultivation and establishing grass unless encouraged to do so by government subsidies.

Hagen and Woodruff (1975) concluded that because of the high concentrations and frequent occurrence of dust storms in the ten Great Plains States, it is doubtful that any of them could meet the maximum 24-hour particulate concentration criterion in the National Ambient Air Quality Standards. Any such standards, if enforced, would bring a storm of protest from farmers and ranchers who feel that their livelihood is threatened. Furthermore, the standards probably would be impossible to enforce in the southwestern and southern Great Plains States simply because occasional severe dust storms are a natural occurrence there, due to the sandy soils, sparse vegetation, high winds, and periodic droughts.

Wind erosion control on the less susceptible cultivated soils can be accomplished by residue management, strip cropping, windbreaks, and emergency tillage. Windbreaks have become less popular than they were in the 1930s and 1940s because the old eight- and ten-row shelterbelts took relatively large amounts of land out of cultivation. Newer shelterbelts use only one or two rows of grasses, shrubs, or trees, and farmers are more receptive to them. With the advent of center-pivot irrigation systems, windbreaks that interfered with their operation have been removed.

An aggressive technical assistance program would probably result in wind erosion control being adopted in the more favorable areas by many more producers than are now involved in conservation programs. There will remain, however, a core of less educated and less affluent farmers and ranchers who will not undertake effective programs. That group will require an intensive educational program and some financial inducements. On the dry margins of the dryland farming areas, financial assistance or land use regulations will be needed to retire erosion-prone land from cultivation. (Almost any kind of land use control program is certain to be opposed vehemently.)

As already noted, water erosion control measures are more likely to be profitable in the short term in the wetter areas than in the drier ones. Government support for water erosion control is needed more, then, in the less favorable climatic zones. However, if erosion control on cultivated land is combined with water conservation in the drier zones, as it usually is, the combination serves to increase yields while reducing erosion. Most of the yield benefits are due to water conservation rather than to soil conservation.

As with wind erosion, an aggressive technical assistance program may well be enough to bring about significant improvement in water erosion control. Again, the less affluent and less educated farmers will require a special effort to persuade them to initiate a suitable erosion control program.

Grazing Land: Areas with limited cover, fine-textured, easily dispersed soils, and sloping terrain, are most easily eroded. These areas commonly occur on soils derived from shale. Rangelands exposed by trampling and overgrazing are especially vulnerable.

Much of the Colorado River basin is in the shale lands category. Western Colorado near Grand Junction, eastern Utah, the Little Colorado in Arizona, and several areas in New Mexico have special problems.

Valley trenching has occurred on shaley fine-grained alluvial fill in portions of the Little Colorado in Arizona. In the Rio Puerco Valley about two-thirds of the sediment comes from gully and arroyo trenching and piping, and slightly less than one-third from sheet and rill erosion.

The chapparral areas located in the San Gabriel, San Bernardino, and San Andreas Ranges of Southern California are very susceptible to erosion where soils on sloping terrain are subject to long-duration and high-intensity rains. Destruction of plant cover and ground litter by frequent wildfires and by human encroachment including road and building construction on poorly chosen sites, has caused severe erosion problems including mass movement of soil.

In much of the desert areas of Arizona, California, Nevada and eastern Oregon erosion is depressed because of limited runoff. Also, in much of the very arid areas the formation of desert pavement or surface armoring with rock protects underlying soil from wind and water erosion.

In Montana geologic erosion of barren or nearly barren areas where Pierre and Bearpaw marine shales outcrop at the surface in the central and eastern part of the State is serious. Gully erosion and downstream valley trenching are also problems in these basins.

Sheet and rill erosion rates on rangeland and pastureland vary from state to state, from about one ton per acre to almost 14 tons per year. The

Western regional average is 4.49 tons/acre; data are presented in table IV-21.

The Agricultural Research Service in 1974 estimated that more than 71 percent of the rangelands in the 17 Western States were in only fair to poor range condition (table IV-7). As previously discussed, there is a high correlation of range condition to degree of erosion. Reduced vegetation, excessive runoff, and blowing and erosion go together. Much of that same 71% probably also has moderate to severe erosion (Dregne, 1979).

In order to devise some approximation of the federal rangeland soil losses for the 17 Western States, the estimated average annual sheet, rill, and wind erosion on the intermingled nonfederal rangeland is given in terms of tons/acre when applied to the federal rangeland acreages, resulting in an average total of 5.28 tons per acre (table IV-21).

The validity of applying the nonfederal rangeland erosion rates to the federal rangelands may be rather tenuous. The nonfederal lands by virtue of the settlement selection processes are probably less frail than the land left in federal ownership, but on the other hand, they are subject to a greater degree of grazing, and water concentration.

BLM has made a state-by-state comparison of erosion condition on its Western lands with those in state and private land. This reveals a somewhat greater degree of critical and severe erosion on BLM-managed land than on state and private lands (7.1% to 6.0%). Moderate erosion is slightly more on BLM lands (33.6% to 32.3%); stable or slight erosion conditions prevail on 59.3% of the BLM lands and 61.7% on state and private lands (table IV-20). But in general the differences between Federal and non-Federal lands is small.

Water erosion is the principal erosion problem on grazing lands. Wind erosion is important on loose sandy soils, especially in the southern part of the arid West. Both are the result of overgrazing. As with cultivated lands, the economic feasibility of controlling water and wind erosion decreases as the average annual precipitation decreases. The principal reason is that establishing and maintaining a good vegetation cover becomes more difficult in the more arid climatic zones. Rangelands cannot pay for construction of terraces and other erosion control structures except under special circumstances. Consequently, manipulation of livestock and vegetation are the main techniques that can be used. The objective is to have sufficient plant cover to protect the soil from the destructive force of wind and water.

Seeding grasses and improving grazing management are the principal requisites for erosion control. Since one of the first things needed for improvement is to reduce grazing pressure, range improvement generally equates with an economic loss from the treated land during the years when the plant cover is being established or improved. It is this loss in income that dissuades ranchers from undertaking major range improvements. Government financial assistance is needed to help most private landowners get through the initial period of reduced income. Instituting an improvement program on federal lands can be done, but rancher opposition has been, and remains, strong against any reduced grazing.

Forested Land: Most of the forest areas have a light or moderate erosion because of stable soils and good vegetation cover. Most of the erosion problems are generally very localized and are related to construction mining, logging, grazing, and recreation activities, Some exceptions in forested areas where critical erosion and sediment occur are:

o In Northwest California, which is a combination of forest and grassland. Here rains of medium duration and high volume and intensity saturate the unstable soils on steep slopes and produce large volumes of runoff with high peaks. Excessive grazing, disturbance of the soil by animals over extensive areas, careless logging, and improper road construction and maintenance are the main sources of accelerated erosion.

o Soils of much of the forested area in central and southwestern Idaho are considered unstable when disturbed weathers into shallow sandy soils. The mantle depth is only a few inches on millions of acres in the Salmon River valley, Boise Range, and Sawtooth Mountains.

o With loss of cover, the Wasatch Front soils are highly erodible. The extremely high natural geologic erosion rates have formed the scenic beauty of several unique national parks and monuments in the Utah area.

Urbanized Land: Subdivision development accelerates rates of erosion and creates problems of downstream deposition in many of the rapidly developing urban areas of the West. Disturbed soils are susceptible to erosion and mass movement due to bare ground exposure. It is estimated that close to a quarter of a million acres are being converted to urban areas annually. This area is susceptible to accelerated erosion for a 3-5 year period.

Highway construction causes problems due to lack of early stabilization of cuts and fills in many areas.

Nutrient Loss

Calculations based on soil erosion data suggest that nationally, more than 50 million tons of plant nutrients (nitrogen, phosphorus, potassium) are lost annually from cropland soils (Wadleigh, 1968). The cost of "replacing the nitrogen, phosphorous, and one-fourth of the potassium" in the entire U.S. agricultural soil was estimated to be $6.8 billion about 10 years ago (Beasley, 1972).

The Comptroller General, in a 1977 report, cites a figure of $1.2 billion as the market value of fertilizers needed to replace the nutrients lost through erosion that year. While that figure refers to total U.S. loss, the magnitude of erosion in the Great Plains and the Pacific Northwest indicated that Western erosion probably accounted for a nutrient loss worth as least $500 million (Dregne, 1980).

Nearly sixteen million tons of fertilizer were consumed in the West in 1977, practically all of which were used on croplands, a jump from the 13 million tons used two years earlier. It must be noted that 1976 and 1977 were drought years.

Decreased yields are the result of the loss of soil nutrients. It has been found that desertification of dry-farmed lands due to this loss of nutrients has reduced yields on sandy lands by 30 to 40 percent and on hardlands by 20 to 30 percent (Dregne, 1978). Using a conservative figure of 25 percent decrease in yield due to desertification, there is an annual reduction of wheat yields in the semiarid West of about 300 million bushels (Dregne, 1978). Assuming wheat were $3.00/bushel, this would be a $900 million loss in revenue from wheat alone. Similar reductions of grain sorghum yields will be found throughout the Great Plains States. High-valued crops are not as affected by desertification since they are more intensively managed (irrigated and fertilized) and are grown on the better soils.

While nutrients in the cropland are a valuable asset, they are washed into streams and water bodies where they can be a detriment. Nutrients contained in waters are a stimulant to the growth of algae in surface-water bodies receiving such wastes. Problems stemming from this fact have been growin rapidly in all parts of the country, and specialists in the field are anticipating the time when requirements for wastewater treatment will have to be revised to include removal of nutrients. The two major offenders are nitrogen and phosphorous, both of which are abundant in water drained from land surfaces; in rainwater itself; in waste discharges from cities and industry; in agricultural runoff; and in feedlot runoff (Geraghty, 1977).

More than half of the surface-water bodies in the country are believed to be affected to some degree by nutrient-rich wastewater (Geraghty, 1977), and in figure IV-6 the relationships between land uses and nutrient concentration in streams is presented. The dramatic increase in the usage of phosphates, nitrogen, and potash during the last thirty years in Nebraska is an example of the direct relationship between irrigation and primary nutrient consumption, and is shown in figure IV- 7. Reuse of irrigation outflows could be a means to controlling the loss of nutrients from irrigated farming operations.

Compaction and Crusting

Compaction: Soil compaction is a serious problem in many cultivated areas. It varies with the kind of soil, the amount of organic matter, the surface texture, the kind and weight of the tillage equipment, and the moisture content of the soil when it is tilled. There is adequate evidence that compaction and poor soil structure lower crop yields, decrease the rate of water infiltration, and increase runoff and erosion, but the direct cause-and-effect relationships are not well understood.

Tractors and tillage implements tend to form a compact layer in the soil at the bottom of the tilley layer (Doneen and Henderson, 1953). Root and water penetration into these plow pans or tillage pans is restricted. Man-induced compacted subsoil layers are common in fine-textured irrigated soils, especially, and in medium and moderately coarse-textured dryland soils. The adverse effect of these relatively dense layers is due to the reduction they cause in the ease of root and water penetration into deeper horizons and to the reduced soil volume the roots occupy. Surface runoff is increased, plant growth is reduced, and crops become more susceptible to drought when it occurs.

Subsoil compaction on cultivated lands is common wherever tillage is done to about the same depth year after year. Breaking up the pay is done by varying tillage depth. Avoiding tillage when soils are wet is a preventive measure.

Compaction of cultivated soils can be reduced by timing tillage operations for periods when soils are relatively dry, by utilizing minimum tillage practices, and by varying the depth of tillage. Soil crusting is the result, in the great majority of cases, of the soil being low in organic matter and without good vegetation cover. Those are also the conditions that make soils susceptible to accelerated wind erosion. As with wind erosion control, the best way to minimize soil crusting is to provide adequate plant cover to protect the soil.

Range soils experience surface compaction and crusting by the hooves of animals. Some compaction occurs whenever grazing occurs, but the effect is much more pronounced when the land is overgrazed and has little vegetation protection. The absence of vegetation cover

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increases soil crusting and compaction, which increases runoff and reduced water intake, which further reduces herbage production and once more increases the runoff and compaction hazard. And so range deterioration gets progressively worse. As Rauzi and Fly (1968) noted, water intake rate, range condition class, and herbage production on rangelands tend to vary together on a specific type of range site. Water intake on one silty site was 0.95 inches (2.5 cm) per hour for a range in fair condition and 3.37 inches (9.6 cm) per hour for a range in excellent condition.

Soil compaction, by increased runoff, increases both erosion and downstream flooding. Documentation of the amount of damage resulting from compaction alone is not available. The extensiveness of the problem in arid regions indicates that the environmental impact should be large in the aggregate even though relatively small on any one field.

Crusting: Surface crusts are a major structural feature of many arid region soils (Cary and Evans, 1974). Crusts also increase runoff and erosion and interfere with seedling emergence. They are most common in nature when soils are low in organic matter, high in silt, or high in exchangeable sodium, all of which lead to unstable soil structure. Cultivation and overgrazing tend to increase soil crusting by exposing the soil to the impact of raindrops, which effectively destroys the original structure and causes crusting.

High-frequency sprinkler systems have a similar effect on unprotected irrigated soils. As with soil compaction, data on the damage done by soil crusts are not available. It is obvious, however, that the problem is a significant one when a light rain can stop seedling emergence over large parts of a field (Dregne, 1980).

Salinization of Soils

Salinization of soils is one of the serious problems that can appear in irrigated agriculture. This type of farming requires enough water for crops to grow, and for soils to flush the salts left behind by evaporation. If salts are not flushed away, the roots of plants find it increasingly difficult to abstract, from the soil/water system, the water they need to survive and thrive. This is due to changes in the osmotic pressure of water as it becomes more and more saline. (See table IV-22 and figures IV-8 and IV-9.)

Salinization of dry-farmed land is said to be the number one soil problem in the northern Great Plains (Vander Pluym, 1978). The problem is referred to as saline seepage. Dryland saline seeps are the result of excess soil moisture seeping out along slopes or in valleys. Saline seeps are increasing in size and severity in the United States and across the border in the prairie provinces of Canada. About 2 million acres (0.8 million hectares) of dryland are severely affected by saline

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seepage (U.S. and Canada) and another 7 million acres (2.7 million hectares) are affected to a lesser degree. A survey in Montana showed that dryland saline seeps increased from 53,000 (20,000 hectares) in 1959 to 156,000 acres (60,000 hectares) in 1975. The total impact of the salinity problem has not been completely measured but it has been recognized that the amount of affected cropland is growing.

Effective measures have been developed to control dryland saline seepage. They consist of (1) preventing the formation and deep percolation of excess moisture in the recharge area; (2) draining groundwater from the seep spots; and (3) growing salt-tolerant crops. Prevention is the preferred measure (Dregne, 1980).

There are three common ways to alleviate the salt problem in the soil in irrigated areas. The first method is to allow natural precipitation to leach the salts below the rooting zone. This system is used primarily in low intensity irrigation projects where there are low amounts of soluble salt present or where the precipitation occurs at the appropriate season. Winter rains are especially effective in removing salt from the soil. A second method is installation of tile drains to remove salty water from the profile. This is effective in areas which also have problems of waterlogging. A third method is adding excess water to leach salts from the profile, in conjunction with subsurface drainage. The salt content of the soil can usually be kept at a satisfactory low level as long as the flow of water is down or away from the rooting zone.

Control of the dryland saline seep problem calls for intensive cropping, growing deep-rooted perennial plants, and draining wet areas. The first two practices can be carried out by the farmer; land drainage is a practice which frequently is cost-shared by the farmer and the federal government (Dregne, 1980).

Waterlogging

Waterlogging of soils is the other serious problem associated with irrigated agriculture. It arises when the infiltration rate of the soil exceeds the permeability (hydraulic conductivity) of some horizon within the soil. In that event, water accumulates within the profile and adversely affects root growth. Waterlogging can be controlled by reducing the amount of irrigation water applied, improving water and land management practices, and by draining the soil with open or closed drainage systems.

There are no good data on the amount of salinized and waterlogged irrigated land in the 17 Western States. A figure of 25 percent has long been used for the amount of land affected seriously enough to reduce crop yields. The main affected areas are in the Colorado and Rio Grande watersheds, the Great Basin region, and the Imperial and San Joaquin valleys of California.

The problem of waterlogged soils is not a recent phenomenon. Problems of waterlogging were encountered by prehistoric Indian tribes in southern Arizona (Skibitzke et al., 1963). They used brush dams to divert water into a canal system. The gradient of the canals was less than that of the streams, and the land became waterlogged. After several hundred years, their agricultural enterprise failed due to waterlogging. Waterlogging is still a problem in irrigated agriculture, and it increases with the area irrigated. For the 17 Western States, the irrigated area has increased from just over 2.5 million acres (one million hectares) in 1889 to 35-51 million acres (14-19 million hectares) in 1977. The distribution of irrigated land for these 17 states is shown in table IV- 23.

Waterlogging is a problem that is usually profitable for the individual farmer to correct if it is due to on-farm conditions. If high water tables are due to seepage from streams or community canals or neighboring lands, then some kind of government financing is expected to pay the cost of drainage. Drainage districts, as legal entities, are one means of obtaining community action and government financing for large scale drainage works.

Water Salinity Buildup

The concentration of dissolved solids in streamflow is of great concern in most of the Western United States (figure IV-10). This concentration occurs partly because some of the water withdrawn for such uses as irrigation returns to the stream bearing dissolved material. Irrigated agriculture would seem to offer the solution to problems of arid land degradation. With irrigation, crop yields improve, erosion control is facilitated, new crops may be grown, and a more stable economy is possible than when there is complete dependence on natural precipitation. However, a price is exacted for that favorable situation. All irrigation water, regardless of its source, contains dissolved salts, and these salts find their way into surface and ground waters if certain precautions are not taken.

Another factor influencing salinity buildup is the evaporation of water from reservoirs, leaving the salts, whose concentration is increased. Also, any diversion of flow leaves less water to dilute high salt concentrations due to natural causes, such as salt springs. Further, consumptive losses associated with municipal and industrial water uses, evapotranspiration losses from native vegetation on noncropped land, and out-of-basin diversions of water are other causes of increasing salinity even if no more salt is added to the system (NWC, 1973). The salinity problem is increasing not only in surface waters but in ground waters as well. Salinity problems are in general related to poor drainage, inappropriate irrigation practices, and disturbances of saline geological formations and soils.

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Salinity affects agricultural productivity, and about 25% of the irrigated land in the U.S. suffers from some degree of salinization and/or waterlogging.

Erosion is also a major contributor to salt loading in Western streams. Soils high in salt content such as marine shales are high contributors and probably the largest diffused source. These salts are highly soluble and are concentrated in surface runoff through erosion.

Critical diffuse salt areas occur in the Western States and are generally associated with outcrop areas or soils derived from soft marine shales. See table IV-24. Over one half of the 10.7 million tons of salt estimated to flow in the Colorado River (see tables IV-25 and IV-26) is from diffuse salt source areas. Soft marine shales of the Pierre and Bearpaw Formations occur in semiarid areas of Montana, Wyoming, and Colorado. The Great Basin has extensive areas of salts occurring in Lake Lahontan and Lake Bonneville sediments; however, much of this salt is located in the Great Salt Lake and various playa lakes associated with ancient Lake Lahontan and Bonneville.

Other critical salt source areas occurring mainly in association with saline marine shales are the Upper Arkansas in Colorado and the Rio Grande and Pecos drainages in New Mexico.

Salts have also built up in soils over time in the Snake River Valley of Idaho, Yakima Valley in Washington, the Imperial, Sacramento, and Tulare Basins in California, and the Closed Basin of the Rio Grande in Colorado because of inadequate leaching under arid climatic conditions (USDI, 1975).

The Colorado River is an example of quality problems caused by dissolved solids. Generally, flows in the headwaters of the Colorado River are of high quality, usually with less than 50 parts per million (ppm) of dissolved solids, but the concentration increases progressively downstream from both natural and manmade causes to about 20-fold. At Imperial Dam, in the Lower Colorado River Basin, the measured flows have had an average concentration of about 865 ppm. If present trends continue, it is estimated that the concentration will reach 1340 ppm by the year 2000, two-and-a-half times the recommended maximum allowable concentration for municipal water supplied, and dangerously high for agricultural use (NWC, 1973). This has reduced Salton Sea fisheries production; the productivity of the land base; and the palatability of water supplies for domestic use. It has added treatment costs for municipal supplies, increased corrosion and scaling of pipes and equipment, accelerated fabric wear, and added treatment costs of industrial water and other costs for industrial makeup and processed water (USDI, 1975). It has also

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caused significant reductions in U.S. and Mexican agricultural production. It has been estimated that the damage to agriculture is about $40,000 annually per mg/l salt load and that municipal damages are about $289,000 per mg/l. See table IV-27. In the San Joaquin Valley more than $30 million have been lost yearly as a result of high saline water tables. If irrigation proceeds there in the same fashion as today, in twenty years around 3/4 of a million acres will be affected, with an annual loss of $300 million (Grew, 1979).

It has been estimated that salinity buildup due to irrigation was costing $16 million/year in 1970 in direct damages (EPA, 1974) in the Lower Colorado Basin. Since salinity in water and soil is incresing in the Western and Great Plains States, it is necessary to calculate these damage costs with a greater degree of accuracy. If we consider that today there are approximately 34 million acres of irrigated cropland in the 17 Western States, the magnitude of the potential problem, wherever irrigation occurs without proper safeguards, can be surmised.

Fertilizer and pesticide use has expanded rapidly in the 17 Western States during the last thirty years, in order to maximize crop production (table IV-28). This in turn has impacted heavily on the surface and ground water resources. Under Section 208 of the Federal Water Pollution Control Act Amendments of 1972 which concerns runoff, agricultural, urban and any other nonpoint pollution sources, procedures and methods of control will be adopted. States have completed some management plans, but the two-year timeframe has been recognized as insufficient. Amendments were enacted in 1977 to remedy this, and Section 208 planning is continuing at present.

Data on the cost of complying with Section 208 will be available when the State start implementing plans to abate non-point pollution. From these data the cost of controlling salinity and sedimentation could be extracted and used to calculate the cost-benefit ratios for diverse water management and conservation schemes. One example is the possible down-sizing, with ensuing substantial earnings, of the 96 mgd Yuma Desalting Plant, if irrigation efficiency of the Wellton-Mohawk District can be improved and the drainage flow reduced.

Sedimentation

Sediment, the product of erosion, may cause damage along streams, rivers, lakes, and wherever it is deposited. Sediment can result in overwash, swamping, and increased flooding. It accumulates in reservoirs, increases treatment costs of municipal and industrial supplies, makes navigable streams impassible without dredging, clogs irrigation and drainage improvements, smothers growing plants and spoils harvestable crops, increases maintenance costs of utility and transportation facilities, decreases the recreational value of water, and adversely affects the fishery resource.

The erosion problems occur on both irrigated and nonirrigated lands. Existing erosion control technology has not been universally accepted and used, primarily because of direct or indirect economic considerations (USDA, 1975).

Over four billion tons of soil are picked up each year by the nation's streams, and 25% of this total tonnage is discharged into the oceans. The other 75% is moved around within drainage basins. The dollar amount of damages caused by sediment is difficult to determine, but it has been estimated at over $500 million per year.

In the Western States one-fifth of the sediment produced by erosion ends up in the ocean. The remainder settles, as has been described, in reservoirs, rivers, and lakes, shortening their useful life. In various places it is spread by flooding over the bottomlands of watersheds and interior basins. Additionally, sediment from agricultural areas usually carries with in fertilizer, pesticides, and other materials which also pollute the receiving waters. Sediment runoff also occurs naturally, but is accelerated by agriculture, grazing, timber cutting, mining, construction, dredge and fill operations, streambank cutting--especially during floods, urban and roadway runoff, and other causes. About two-thirds of the sediments come from agricultural lands.

Sediment not only increases the flooding hazard, but interferes with fish survival and reproduction, damages wildlife habitat in overflow areas, and impairs roadside ditches and drains. Realistic estimates of the costs of many of these kinds of damage are not available, but they are substantial. Table IV-29 shows annual sediment yield by region.

The Water and Power Resources Service has noted that the Eel River in Northwest California has the highest recorded average annual suspended sediment yield per square mile for a large watershed in the United States. About 25 percent of the erosion is from landslides, 65 percent from channel erosion, and 10 percent from sheet and rill erosion. The average annual suspended load from 1957 to 1967 was more than 31 million tons; however, the floods in December 1964 and January 1965 caused a suspended discharge of 160 million tons in a 30-day period. According to the WPRS, in the wheatland area of the Columbia River about 4 million acres are subject to critical water erosion.

In the Rio Grande watershed, overgrazing and poor rangeland management has resulted in an increased shrub-to-grass ratio, and a serious problem of runoff and sedimentation exists. About 800,000 cubic yards of sediment per year are deposited in the Rio Grande floodplain. The Rio Puerco Valley in the upper Rio Grande basin contributes almost half of the measured sediment, although it has less than 9 percent of the water yield and only 20 percent of the upper basin area.

The high-sediment yield areas in Montana are associated with geologic erosion of barren or nearly barren areas where Pierre and Bearpaw marine shales outcrop at the surface and from badland areas, mainly in the central and eastern part of the State. Sediment yield rates as high as 15 acre-feet per square mile per year have been measured in the shale badland areas. Numerous small reservoirs have filled with sediment in a few years.

The dredging of sediments from U.S. rivers and harbors costs the nation about $250 million annually. Of this total, it seems reasonable to believe that at least $100 million is spent in the West. The loss of reservoir capacity is estimated to cost the country about $50 million annually and most of this occurs in the West. These and other sediment damages are estimated to cost the United States $500 million annually of which more than half occurs in the Western States.

Table IV-1

Brush on Federal and Nonfederal Land

- Acreages x1000 -

Region	Grazing Land Acreage Federal	Grazing Land Acreage Nonfederal	Acreage in Brush Federal 1963	Acreage in Brush Federal 1973	Acreage in Brush Nonfederal 1963	Acreage in Brush Nonfederal 1973
Great Plains	5,225	201,589	2,302	2,733	113,392	114,348
Mountain	167,411	197,224	84,295	88,728	105,234	105,050
Pacific	40,147	37,951	22,777	23,687	23,148	22,382

Source: USDA, RCA, 1980.

Table IV-2

Brush on Federal and Nonfederal Land (1973)

- Percentages -

Region	% of Total Grazing Land Covered by Brush		% of Grazing Land in Medium and Dense Stands of Brush	
	Federal	Nonfederal	Federal	Nonfederal
Great Plains	52	57	74	74
Mountain	53	53	53	50
Pacific	59	59	52	53

Source: USDA, RCA, 1980.

Table IV-3

Non-federal Rangeland: Extent, Condition and Estimated Losses in Cattle Production (1977)

State	Acreage	Average Range Condition		
		Excellent + Good	Fair	Poor
Arizona	35,092	33%	45%	22%
California	17,555	19%	35%	46%
Colorado	23,802	40%	44%	16%
Idaho	6,586	21%	50%	29%
Kansas	16,272	55%	34%	11%
Montana	38,833	54%	39%	7%
Nebraska	22,001	46%	35%	19%
Nevada	7,349	17%	55%	28%
New Mexico	42,096	26%	57%	17%
No. Dakota	10,564	64%	26%	10%
Oklahoma	14,569	48%	41%	11%
Oregon	10,109	38%	35%	27%
So. Dakota	22,199	60%	32%	8%
Texas	95,401	36%	46%	18%
Utah	9,362	23%	49%	28%
Washington	6,041	43%	41%	16%
Wyoming	26,171	50%	44%	6%

Table IV-3 - continued

Cattle Marketing in Lbs/Acre by Range Condition			Cattle Losses Due to Less Productive Range
Exc. + Good @ 14.3 Lbs/acre Total Production	Fair @ 11.2 Lbs/Acre Total Production	Poor @ 8.9 Lbs/Acre Total Production	Total Lbs.
165,599	176,864	68,710	245,574
47,697	68,816	71,870	140,686
136,147	117,296	33,894	151,190
19,779	36,882	16,998	53,880
127,979	61,964	15,930	77,894
299,868	169,623	24,193	193,816
144,723	86,244	37,204	123,448
17,868	45,270	18,314	63,584
156,513	268,741	63,691	332,432
96,682	30,762	9,402	40,164
100,002	66,901	14,263	81,164
54,932	39,627	24,292	63,919
190,467	79,561	15,806	95,367
491,124	491,506	152,832	644,338
30,792	51,379	23,330	74,709
37,146	27,740	8,602	36,342
187,123	128,971	13,975	142,946

Table IV-4

Condition of Selected Rangeland Ecosystems in the United States, 1976

(Each row totals approximately 100%)

Ecosystem	% High	% Moderately High	% Moderately Low	% Low
Contiguous States:				
Grasslands				
Annual Grasslands	13.2	5.0	36.7	45.0
Plains Grasslands	14.7	34.2	39.6	11.5
Prairie	13.9	34.2	38.1	13.7
Grassland Ecosystems Total	14.3	32.5	39.4	13.8
Shrublands				
Texas Savanna	16.4	23.5	45.9	14.2
Southwestern Shrubsteppe	10.5	14.8	41.5	33.2
Pinyon-Juniper	9.1	28.6	44.4	18.0
Shrublands Ecosystems Total	14.5	30.4	36.7	18.3

Source: USDA, RPA, Review Draft.

Table IV-5

Ecological Condition of Western Rangeland Ecosystems, 1976[1]

(Thousand Acres)

Ecosystem	Total	High	Moderately High	Moderately Low	Low
Grasslands	287,629	43,730	93,451	112,185	38,263
Mountain Grasslands	26,871	4,705	9,725	8,392	4,049
Mountain Meadows	3,285	1,063	1,276	692	254
Plains Grasslands	175,233	25,808	59,878	69,373	20,177
Prairie[2]	39,057	5,579	13,701	15,255	4,520
Desert Grasslands	24,744	2,086	6,109	12,483	4,066
Wet Grasslands[2]	1,511	256	417	311	526
Annual Grasslands	10,153	1,336	510	3,731	4,576
Alpine	6,775	2,897	1,835	1,948	95
Shrublands	294,995	45,873	91,666	104,512	52,943
Sagebrush	129,961	16,023	46,826	45,602	21,510
Desert Shrub	81,171	14,130	29,581	25,547	11,913
Shinnery	4,726	780	1,307	1,915	724
Texas Savanna	28,429	4,666	6,689	13,037	4,037
Southwestern Shrubsteppe	43,218	4,535	6,398	17,925	14,359
Desert	7,490	5,739	865	486	400

Table IV-5 continued

Total Grass and Shrub Lands	582,624	89,603	185,117	216,697	91,206
Chapparral - Mountain Shrub[3]	14,120	1,654	3,083	5,442	3,941
Pinyon - Juniper[3]	47,304	4,285	13,509	21,012	8,498
Total Chapparral-Mtn. Shrub and Pinyon-Juniper	61,424	5,939	16,592	26,454	12,439
Total All Ecosystems	644,048				

1. For definition of condition class see text.
2. Condition class acreages subjected to proportionate adjustments from national figures.
3. Considered as other forest in land use acreage tables.

Source: Forest Service, USDA: RPA

Table IV-6

Percent of Range Grazed, by Ownership and Geographic Region in the Western States, 1976

		Federal Lands Administered by				
	All Ownerships	All Federal	Forest Service	Bureau of Land Management	Other Federal	Non-Federal
Rocky Mountains and Great Plains	91	80	76	88	39	96
Pacific Northwest	60	59	48	84	>1	63
Pacific Southwest	65	49	57	49	4	79
Total	72	63	60	74	15	79

Table IV-7

Rangeland condition in non-forested ecosystems, 17 western states, 1972.*

Ecosystem	Range condition			Area
	Good %	Fair %	Poor %	acres
Western rangelands	17.6	50.0	32.3	418,625,000
Great Plains	48.3	44.9	6.8	228,859,000
Total	28.5	48.2	23.3	647,484,000

* Source: Agricultural Research Service, 1974.

Table IV-8

Cash Receipts from Farming and Value of Home Consumption, 1977

(thousands of dollars)

	Farm Marketings			
	Livestock and Products	Crops	Government Payments	Value of Home Consumption
Great Plains	10,765,130	9,048,501	789,214	141,556
Mountain	4,314,758	2,823,452	221,212	73,682
Pacific	3,778,020	8,333,756	157,533	140,113

Source: USDA, Agricultural Statistics, 1978

Table IV-9

1977 CASH RECEIPTS AND HOME CONSUMPTION VALUES

(IN BILLIONS OF DOLLARS)

	USA	17 Western States	Percent
Livestock	48.5	19.15	40.7
Crops	48.9	22.08	45.1
Total	97.4	41.23	42.3

Table IV-10

WIND EROSION ON CROPLAND AND RANGELAND IN THE GREAT PLAINS STATES, 1977

State	Cropland				Rangeland			
	Erosion, Tons/Acre/Year				Erosion, Tons/Acre/Year			
	<2	2-4.9	5-10	>10	<2	2-4.9	5-10	>10
	(1,000 Acres)							
Colorado	1,195	1,777	1,308	3,151	10	67	53	434
Kansas	7,381	3,941	2,861	2,182	168	113	86	306
Montana	3,722	3,757	1,869	1,546	40	—	—	—
Nebraska	2,923	1,625	733	645	952	237	30	110
New Mexico	245	344	439	787	9,837	4,823	3,318	6,628
North Dakota	11,135	6,603	2,301	303	127	47	20	102
Oklahoma	2,566	1,377	1,145	1,024	7	15	15	--
South Dakota	5,015	5,603	2,120	595	19	8	—	—
Texas	2,092	1,962	3,521	11,964	4,874	2,544	1,979	5,130
Wyoming	283	269	383	206	531	408	178	641
Total	36,557	26,258	16,680	22,403	16,565	8,252	5,679	13,351

Table IV-11

Estimated average annual wind erosion from cropland, in tons per acre, in the Great Plains States (1977)

Great Plains states	All cropland	Land capability class and subclass				
		IIe	IIIe	IVe	VIe	IIs
	Tons per acre					
Colorado-----	8.9	3.9	5.2	11.9	15.2	3.1
Kansas-------	2.9	2.2	2.4	6.2	8.4	1.7
Montana------	3.8	1.25	3.8	7.2	5.6	2.75
Nebraska-----	1.25	1.05	0.8	2.1	5.9	0.65
New Mexico---	11.5	11.5	10.8	18.5	20.5	6.9
North Dakota-	1.8	2.0	1.8	2.6	2.1	2.5
Oklahoma-----	3.0	2.1	4.1	5.3	3.25	0.6
South Dakota-	3.0	4.1	3.9	4.4	3.6	1.8
Texas--------	14.9	7.0	15.6	57.45	101.55	11.9
Wyoming------	2.4	2.9	3.5	2.3	0.3	4.2

Source: 1977 National Resource Inventories (USDA, 1978)

IV.40

Table IV-12

WIND EROSION IN THE TEN GREAT PLAINS STATES — NON–FEDERAL LANDS

	< 2	2–4.9	5–10	> 10	Tons/Acre/Year
Cropland	36,557	26,258	16,680	22,403	(× 1,000 Acres)
Rangeland	16,565	8,252	5,679	13,351	

Table IV-13

SHEET AND RILL EROSION ON RANGELAND IN THE 17 WESTERN STATES

— NON–FEDERAL LANDS —

Range	< 2	2–4.9	5–10	>10	Tons/Acre/Year
United States	313,285	47,080	21,646	25,761	(× 1,000 Acres)
17 W. States	309,710	46,974	21,600	25,652	
Western States Percent of Total	98.8%	99.8%	99.8%	99.6%	

Table IV-14

SHEET AND RILL EROSION ON PASTURE AND NATURAL PASTURE IN THE 17 WESTERN STATES

— NON–FEDERAL LANDS —

Pasture & Natural Pasture	< 2	2–4.9	5–10	> 10	Tons/Acre/Year
United States	105,110	14,240	7,208	6,995	(× 1,000 Acres)
17 W. States	41,776	4,359	1,387	1,075	
Western States					
Percent of Total	39.7%	30.6%	19.2%	15.3%	

Table IV-15

SHEET AND RILL EROSION ON CROPLAND IN THE 17 WESTERN STATES

— NON-FEDERAL LANDS —

Cropland	< 2	2–4.9	5–10	>10	Tons/Acre/Year
United States	200,782	115,372	55,971	41,077	(× 1,000 Acres)
17 W. States	121,732	53,703	17,683	8,982	
Western States					
Percent of Total	60.6%	46.5%	31.0%	21.8%	

Table IV-16

Estimated Average Annual Losses of Land by Riverbank Erosion

Region	Areas of Significant Erosion	Average Land Losses
	River Miles	*Acres/Year*
Missouri	1,692	5,000
Arkansas-White-Red	2,300	7,300
Texas-Gulf	1,698	1,045
Rio Grande	250	150
Great Basin	265	150
Columbia-North Pacific	13,500	1,300
California	2,600	3,837

Table IV-17

Existing Streambank Erosion: Bank Miles and Annual Soil Loss in the Western States (not including the Great Plains States)

Watersheds Less than 400 Square Miles

Total Channel Length (stream miles): 1,247,740

Moderate Erosion:

Length (bank miles): 173,738

Soil Loss (tons/mi.): 420

Serious Erosion:

Length (bank miles): 42,943

Soil Loss (tons/mi.): 1,360

Watersheds Greater than 400 Square Miles

Total Channel Length (stream miles): 50,183

Moderate Erosion:

Length (bank miles): 12,519

Soil Loss (tons/mi.): 540

Serious Erosion:

Length (bank miles): 4,615

Soil Loss (tons/mi.): 1,200

Source: DOI, Critical Water Problems Facing the Eleven Western States, April 1975; Derived from SCS data, August 1974.

Table .IV-18

Erosion Condition Classification on BLM Land, 1979 (acres)

State	Stable	Slight	Moderate	Critical	Severe	Total
Arizona	578,054 4.8%	7,201,303 59.9%	3,643,160 30.3%	533,833 4.4%	68,556 .6%	12,024,906 100%
California	1,136,442 11.9%	4,536,810 47.3%	3,382,108 35.3%	486,581 5.1%	45,362 .5%	9,587,303 100.1%
Colorado	747,449 9.6%	2,581,761 33.3%	3,549,712 45.8%	842,306 10.9%	31,334 .4%	7,752,562 100%
Idaho	2,111,948 19.1%	6,117,941 55.2%	2,498,016 22.6%	332,216 3.0%	14,949 .1%	11,075,070 100%
Montana	1,136,423 15.4%	3,804,553 51.7%	1,976,199 26.8%	398,852 5.4%	46,507 .8%	7,362,534 100.1%
Nevada	2,017,593 4.5%	25,335,202 56.9%	15,069,992 33.9%	1,999,520 4.5%	100,356 .2%	44,522,663 100%
New Mexico	948,280 7.8%	4,454,464 36.7%	4,706,610 38.8%	1,837,900 15.2%	178,558 1.5%	12,125,812 100%
Oregon	2,289,808 17.8%	7,007,547 54.5%	3,276,127 25.5%	269,367 2.1%	12,798 .1%	12,855,647 100%
Utah	1,201,043 6.0%	9,033,476 45.4%	7,252,700 36.4%	2,371,637 11.9%	44,167 .2%	19,903,023 99.9%
Wyoming	703,094 4.2%	8,321,794 49.7%	6,398,416 38.2%	1,197,040 7.1%	129,925 .8%	16,750,269 100%

Table IV-19

Erosion Condition Classification on State and Private Land, 1979 (acres)

State	Stable	Slight	Moderate	Critical & Severe	Total
Arizona	212,807 4.1%	2,973,605 56.7%	1,826,148 34.8%	236,174 4.5%	5,248,734 100.1%
California	392,765 27.1%	615,965 42.4%	372,716 25.7%	70,202 4.8%	1,451,648 100%
Colorado	554,404 17.1%	1,383,748 42.8%	1,121,976 34.7%	175,339 5.4%	3,235,467 100%
Idaho	398,103 22.1%	955,184 53.0%	406,100 22.5%	43,623 2.4%	1,803,010 100%
Montana	967,586 17.5%	2,885,937 52.3%	1,505,818 27.3%	161,684 2.9%	5,521,025 100%
Nevada	312,187 6.2%	3,269,666 64.7%	1,243,194 24.6%	226,151 4.5%	5,051,198 100%
New Mexico	489,645 9.6%	2,158,964 42.1%	1,874,878 36.6%	601,276 11.7%	5,124,763 100%
Oregon	574,900 15.7%	2,222,017 60.8%	782,543 21.4%	73,335 2.0%	3,652,795 99.9%
Utah	459,344 10.4%	1,867,037 42.3%	1,606,980 36.4%	477,495 10.8%	4,410,856 99.9%
Wyoming	336,478 3.9%	4,249,827 49.0%	3,514,281 40.5%	581,071 6.7%	8,681,657 100.1%

Source: Bureau of Land Management, Resource Inventory System Division, Denver Service Area, January 1980, private communication.

Table IV-20

Erosion Condition Classification Totals, 1979 (acres)

Ten Western States*

	Stable	Slight	Moderate	Critical	Severe	Total
BLM Land	12,870,134	78,394,851	51,753,040	10,269,252	672,512	153,959,789
	8.4%	50.9%	33.6%	6.7%	.4%	100%
State and Private Land	4,698,219	22,581,950	14,254,634	2,646,350		44,181,153
	10.6¢	51.1%	32.3%	6.0%		100%

*Includes those Western States included in Tables __ and __.

Table IV-21

Estimated Average Annual Sheet, Rill, and Wind Erosion on Nonfederal Rangeland and Pastureland and on Federal Rangeland

(1977)

Region	Total Acreage (x1000)		Total Erosion (Tons/Acre)	
	Federal	Nonfederal	Federal	Nonfederal
Great Plains	5,255	217,996	2.59	3.80
Mountain	167,411	196,725	4.64	4.01
Pacific	40,147	37,860	8.24*	7.80
17 Western States	212,813	425,673	5.28	4.49

*Sheet and rill erosion only - Wind erosion not available.

Source: USDA, RCA, 1980.

Table IV-22

Saline Public Lands in the Upper Colorado River Basin (in acres)

a.

State	Non- & Slightly* Saline	Moderately* Saline	Highly* Saline
Colorado	5,657,070	713,448	469,482
Utah	8,765,609	1,605,498	2,284,893
Wyoming	3,952,122	3,473,510	435,368
TOTAL	18,374,801	5,792,456	3,189,740

Total Moderately and Highly Saline	8,982,196
GRAND TOTAL	27,356,997

b.

*Class	Salinity (mg/l)
Nonsaline	0 to 250
Slightly saline	251 to 1,000
Moderately saline	1,001 to 2,000
Highly saline	More than 2,000

Table IV-22C.

Common Agronomic Soil Salinity Classification System

Salinity Class	Electrical Conductivity at 25°C. of Saturation Extract in Micromhos/Cm Upper Soil Layer	Lower Soil Layer
Nonsaline	< 4,000	< 4,000
Slightly Saline	< 4,000 above 8 inches	4,000 - 16,000 below 8 inches
Moderately Saline	4,000 - 16,000 above 20 inches	> 16,000 below 20 inches
Strongly Saline (Highly)	> 16,000	> 16,000

Upper soil layer = Topsoil, layer of greatest biological activity, ranges in depth from 1 to 24 inches.

Lower soil layer = Subsoil, layer of accumulation of clay, iron and aluminum compounds, and other mineral substances, is generally two to three times the depth of the topsoil.

Source: Bureau of Land Management, The Effects of Surface Disturbance on the Salinity of Public Lands in the Upper Colorado River Basin (1977 Status Report), February 1978.

Table IV-23

Irrigated land in the 17 western states, 1956 and 1978.

State	Irrigated land, millions of acres	
	1956	1978
Arizona	1.15	1.03
California	7.75	9.10
Colorado	2.38	3.03
Idaho	2.41	3.93
Kansas	0.72	3.42
Montana	1.89	3.11
Nebraska	2.01	7.26
Nevada	0.70	1.30
New Mexico	0.80	1.24
North Dakota	0.05	0.15
Oklahoma	0.29	0.90
Oregon	1.58	1.97
South Dakota	0.12	0.41
Texas	6.96	8.95
Utah	1.20	2.03
Washington	0.95	1.64
Wyoming	1.30	1.79
17 western states	32.26	51.27

Table IV-24

THE PERCENTAGES OF SEDIMENT YIELD FROM DIFFERENT SOURCES

Sediment Source	Contribution (Percent)
Streambank	26
Cropland	40
Pasture and Rangeland	12
Forest Land	7
Roadside	3
Urban	4
Mining	1
Other	7
Total	100

Source: SCS Rural Clean Water Program, Environmental Impact Statement (USDA, 1977)

Table IV-25

Average Annual Salt and Water Yields at Selected Gaging Stations on the Colorado River*

Name of Station	Salt Load (tons)	Concentration (mg/l)	Period of Record
Colorado			
Near Hot Sulphur Springs	26,000	64	1947-57
	19,500	80	1966-75
Utah			
Near Cisco	4,363,000	610	1929-57
	3,816,000	614	1966-75
Arizona-California			
Near Mexican Border	9,194,000	938	1977

*Rounded figures.

Source: Bureau of Land Management, The Effects of Surface Disturbance on the Salinity of Public Lands in the Upper Colorado River Basin (1977 Status Report), February 1978.

Table IV-26

Summary of Estimated Total Runoff, Sediment, and Salt Produced from Public Lands in the Three Upper Colorado River Basin States of Colorado, Utah, and Wyoming

YIELDS BY STATE	Salinity Class			
	Highly Saline	Moderately Saline	Non- and Slightly Saline	TOTAL
COLORADO				
Runoff (ac-ft/yr)	7,600	17,900	287,000	312,500
Sediment (tons/yr)	897,000	986,000	8,099,000	9,982,000
Salt (tons/yr)	34,400	19,400	113,000	166,800
UTAH				
Runoff	36,900	40,000	445,000	521,900
Sediment	4,363,000	2,210,000	12,550,000	19,123,000
Salt	167,000	43,600	176,000	386,600
WYOMING				
Runoff	7,000	21,300	201,000	229,300
Sediment	831,000	2,449,000	5,658,000	8,938,000
Salt	31,900	33,300	79,300	144,500
TOTAL OF 3 STATES				
Runoff	51,500	79,200	933,000	1,063,700
Sediment	6,091,000	5,645,000	26,307,000	38,043,000
Salt	233,300	96,300	368,300	697,900

Source: Bureau of Land Management, *The Effects of Surface Disturbance on the Salinity of Public Lands in the Upper Colorado River Basin* (1977 Status Report), February 1978.

Table IV-27

Salinity Damages in the Lower Colorado River Basin

	1974 Dollars	
	Estimated Average $/mg/l	1977 Estimated Damage @ 6.7% Inflation Rate $/mg/l
Agricultural Damages	$ 33,168	$ 40,000
Municipal (Household) Damages		
Metropolitan Water District	$187,000	
Central Arizona Service Area	26,300	
Lower Main Stem	27,200	
	$240,500	$289,000
Industrial Damages	$ 1,500	$ 1,800
Average agricultural, municipal and industrial damages estimated from salinity		$330,800

Source: Bureau of Land Management, The Effects of Surface Disturbance on the Salinity of Public Lands in the Upper Colorado River Basin (1977 Status Report), February 1978.

Table IV-28

Commercial Fertilizer Consumed

(tons)

Region	1975	1977
Great Plains	6,363,609	8,027,664
Mountain	1,653,162	1,875,997
Pacific	5,086,523	5,876,968

Source: USDA, Agricultural Statistics, 1978

Table IV-29

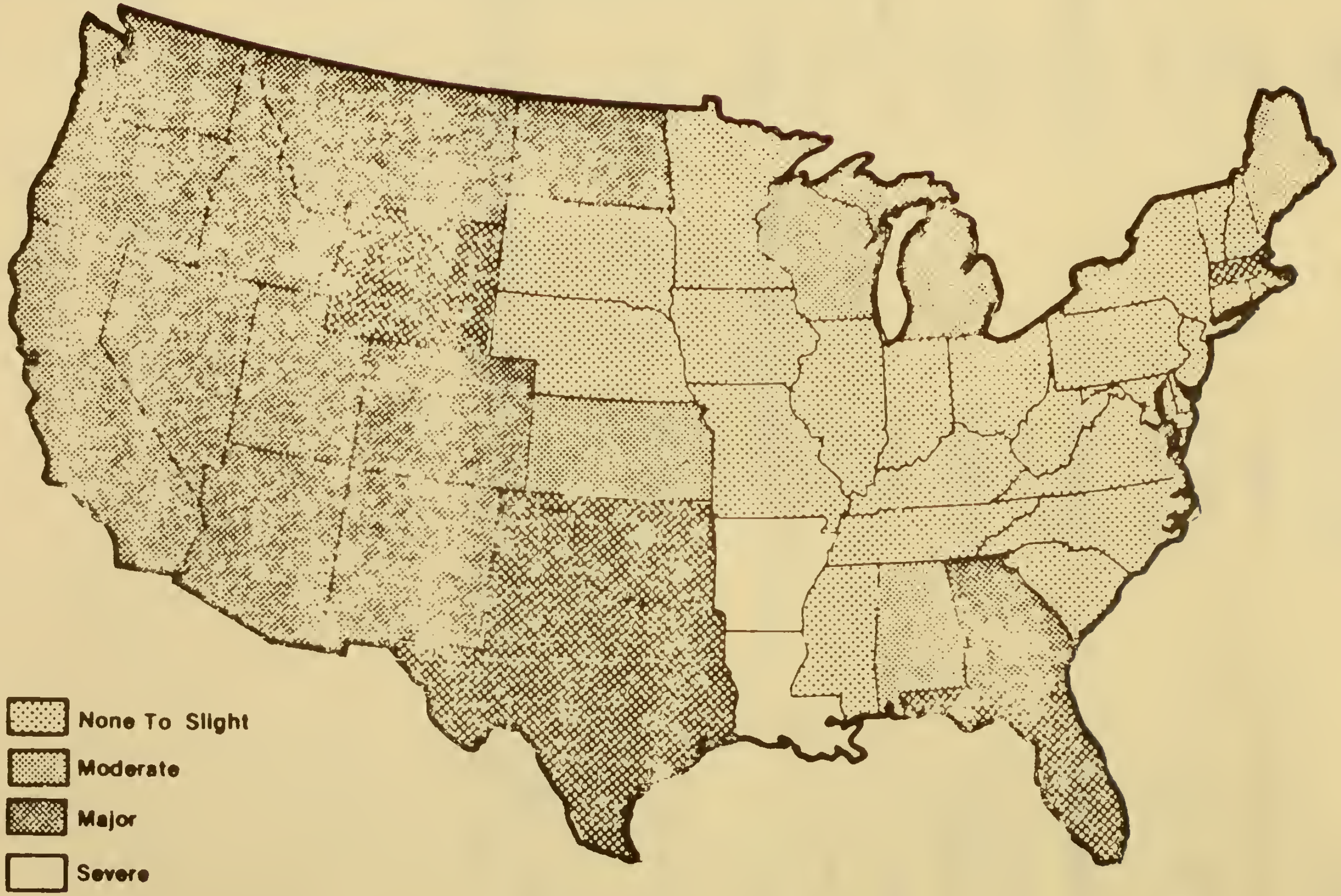
Annual Sediment Yield by Region

Region	Drainage Area (Sq. Miles)	Acre-feet/ Sq. Mile
Columbia-North Pacific	273,784	0.15
California	165,177	0.38
Missouri	221,998	0.27
Great Basin	139,372	0.12 (minimum)
Upper Colorado	113,341	0.45
Lower Colorado	136,333	0.45
Rio Grande	82,277	0.55 (maximum)
Arkansas-White-Red	46,204	0.29
Texas Gulf	5,913	0.35
Westwide Total	1,184,399	0.29

BuRec, USDI,
Source: / Critical Water Problems Facing the Eleven Western States,
April 1975. Developed from SCS data, August 1974.

Figure IV-1

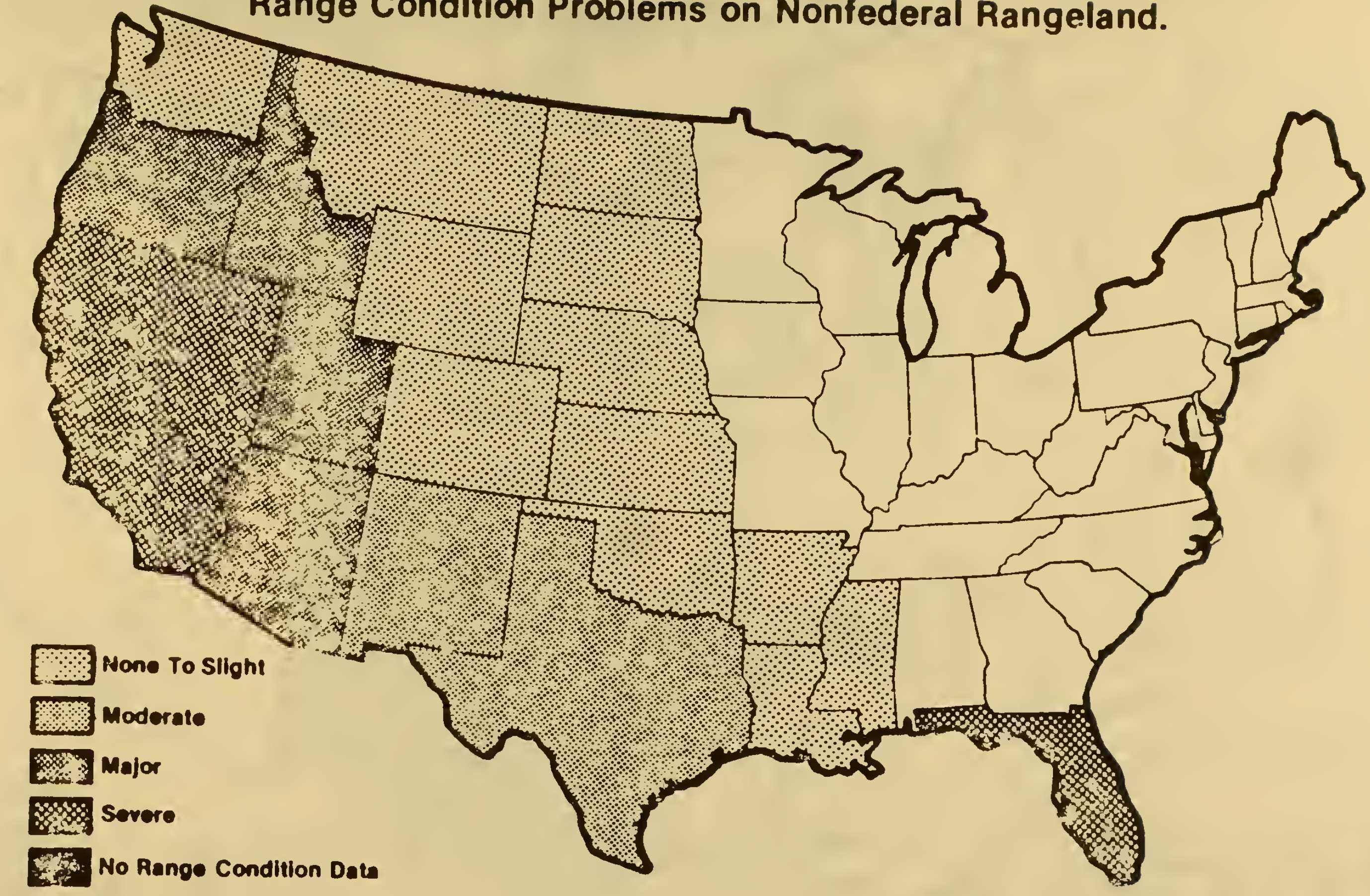
The Brush Problem on Nonfederal Rangeland, Native Pasture, and Pastureland. (1973 SCS Brush Inventory for Nonfederal Lands)



Source: USDA, RCA, 1980.

Figure IV-2

Range Condition Problems on Nonfederal Rangeland.



Unshaded States Have Insignificant Amounts of Rangeland

Figure IV-3

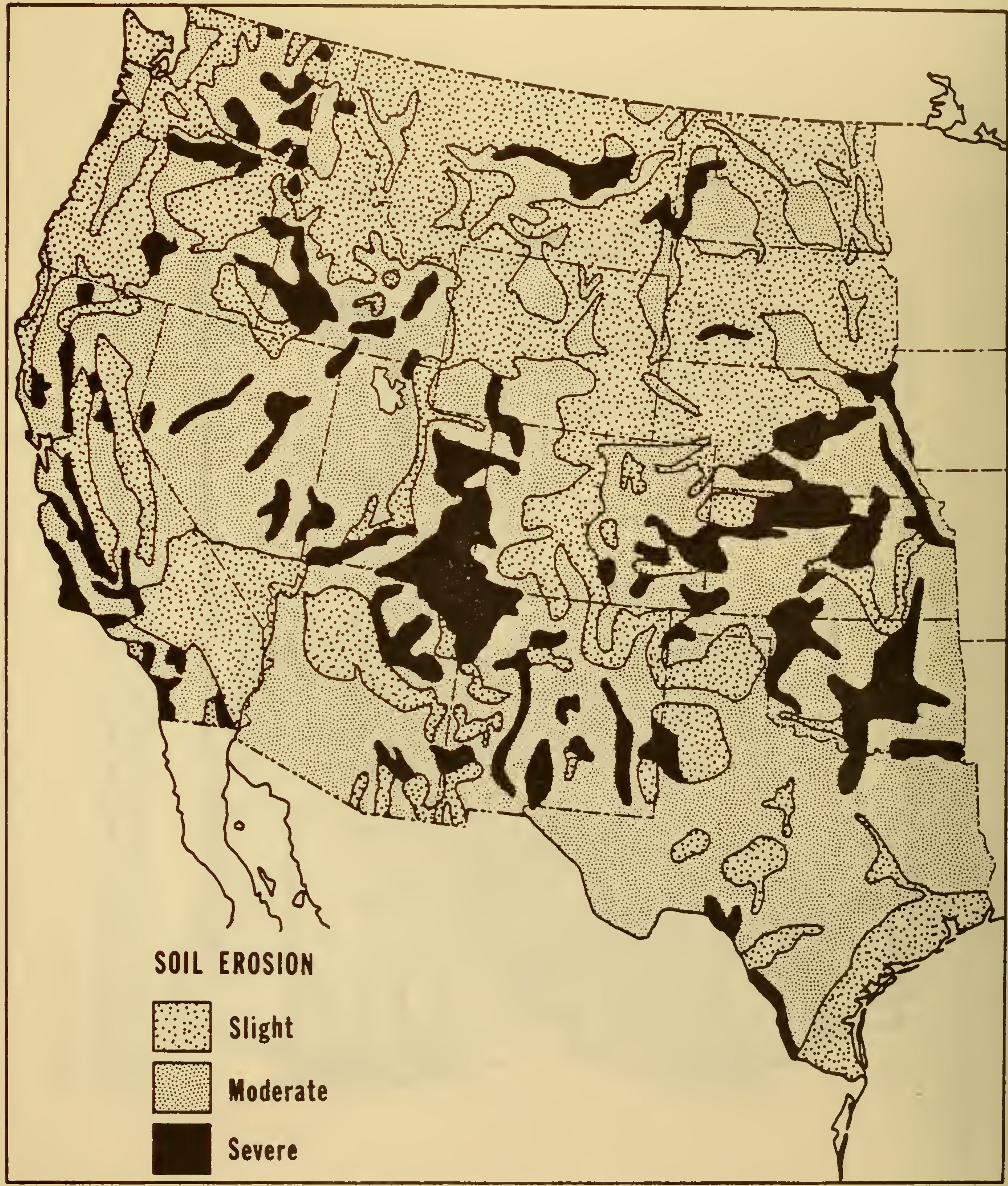


Figure 1. Generalized soil erosion, 17 western states.

Figure IV-4

Wind Erosion on Cropland in the Great Plains States.

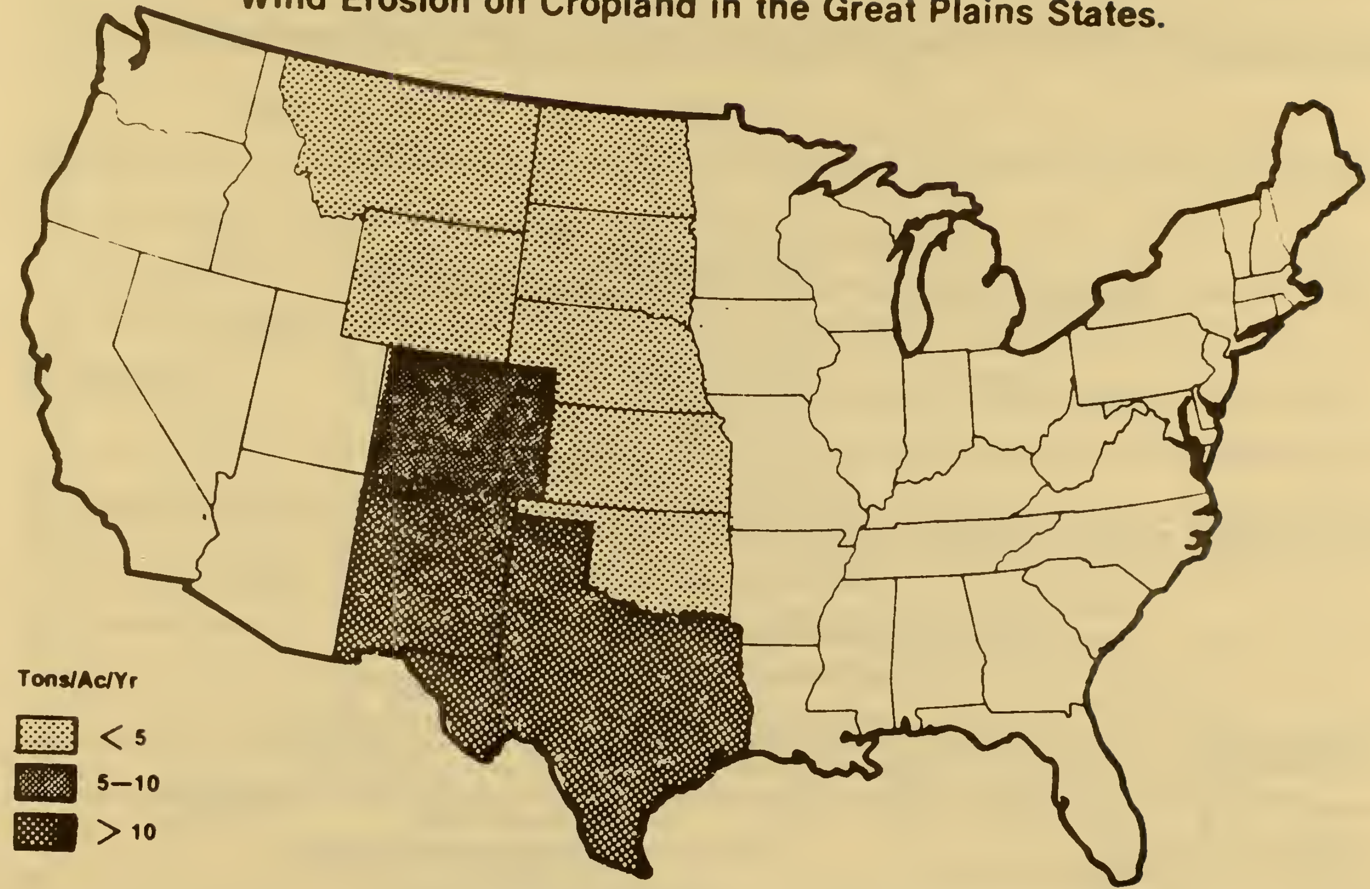


Figure IV-5

Form 7310–12
(August 1970)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

DETERMINATION OF EROSION CONDITION CLASS
SOIL SURFACE FACTORS

By A. AKER
Date 9-6-68
Location 2704003 MAD CREEK
Treatment affecting the SSF

SOIL MOVEMENT	No visual evidence of movement 0 1 2 3	Some movement of soil particles [✓ 4] 5	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. [✓ 6] 7 8	Occurs with each runoff. Soil and debris deposited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have empryonic dunes and wind scoured depressions 12 13 14
SURFACE LITTER	Accumulating in place 0 1 2 [✓ 3]	May show slight movement 4 5 [✓ 6]	Moderate movement is apparent, deposited against obstacles 7 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little in evidence 12 13 14
EROSION PAVEMENT	If present, pavement is well developed and evenly distributed 0 1 2	If present, pavement is well developed but with spotty distribution 3 4 [✓ 5]	Some pavement and/or large rock may be present but distribution pattern is poorly developed 6 7 8	Pavement may be partially developed but exhibits some movement 9 10 11	Pavement may be considerable but dissected by rills and gullies or already washed away 12 13 14
PEDESTALLING	No visual evidence of pedestalling 0 1 2 [✓ 3]	Slight pedestalling, in flow patterns 4 5 6	Small rock and plant pedestals occurring in flow patterns [✓ 7] 8 9	Small rocks and plants on pedestals generally evident, plant roots exposed 10 11	Pedestalled rocks and plants are present 12 13 14
RILLS	No visual evidence of rills 0 1 [✓ 2] 3	Some rills in evidence but less than ½" deep at infrequent intervals over 10' 4 5 [✓ 6]	Rills ½" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 12	May be present at 3" to 6" deep at intervals less than 5' 13 14
FLOW PATTERNS	No visual evidence of flow patterns 0 1 2 [✓ 3]	Deposition of particles may be in evidence 4 5 6	Well defined with intermittent sediment deposits [✓ 7] 8 9	Flow patterns contain silt and sand deposits and alluvial fans 10 11 12	Flow patterns are numerous and readily noticeable. May have large barren fan deposits. 13 14 15
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 [✓ 2] 3	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 [✓ 5] 6	Several well developed gullies having active erosion along less than 10 percent of their length 7 8 9	Gullies are numerous and 10 to 50 percent are actively eroding 10 11 12	Sharply incised gullies cover most of the area and over 50 percent are actively eroding 13 14 15

SITUATION	TOTAL			
○ PRESENT	42	(22 + 20) X 100 = 42 100		
□ FUTURE	22	[(13+9) ÷ 100] X 100 = 22		

Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100

(Instructions on reverse)

Figure IV-6

Relationships between Land Use and Nutrient Concentrations in Streams

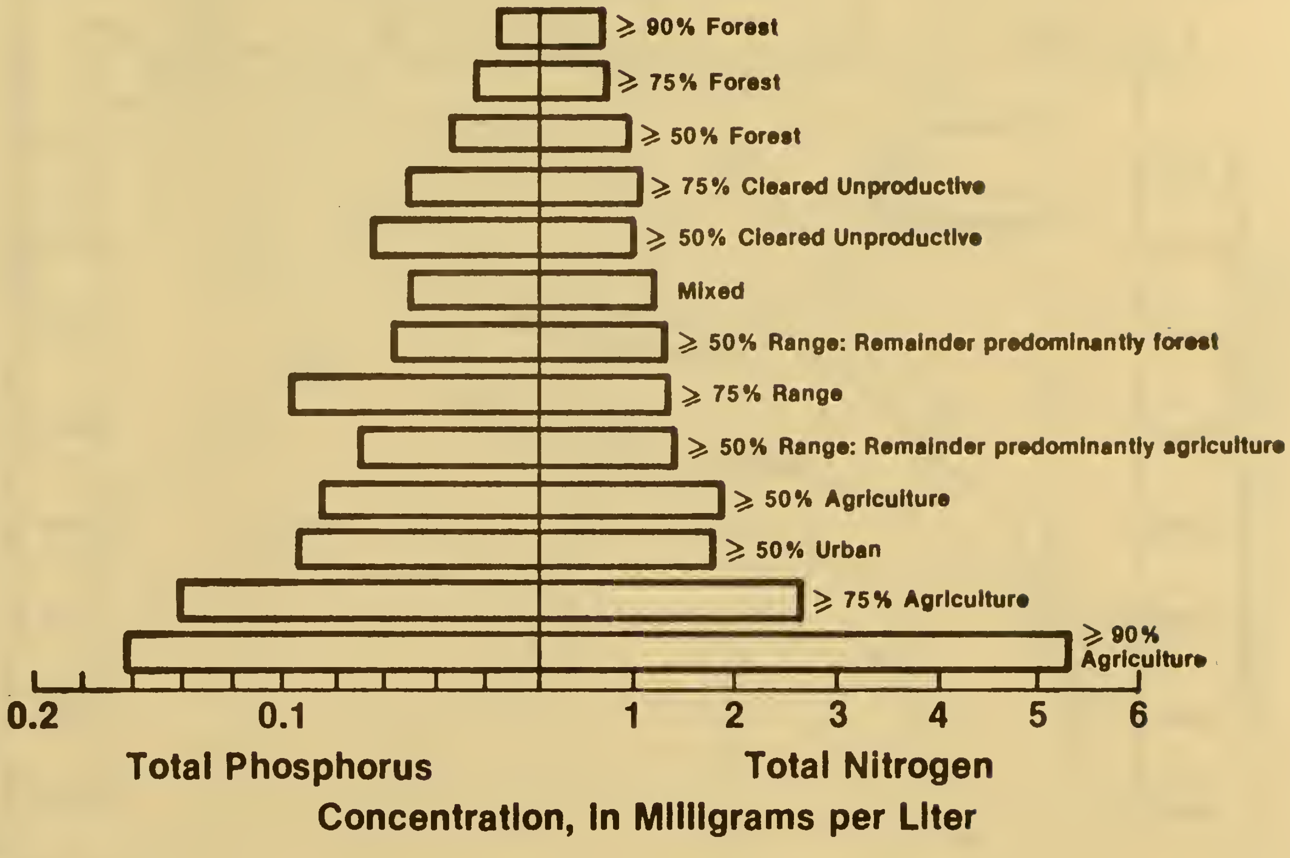
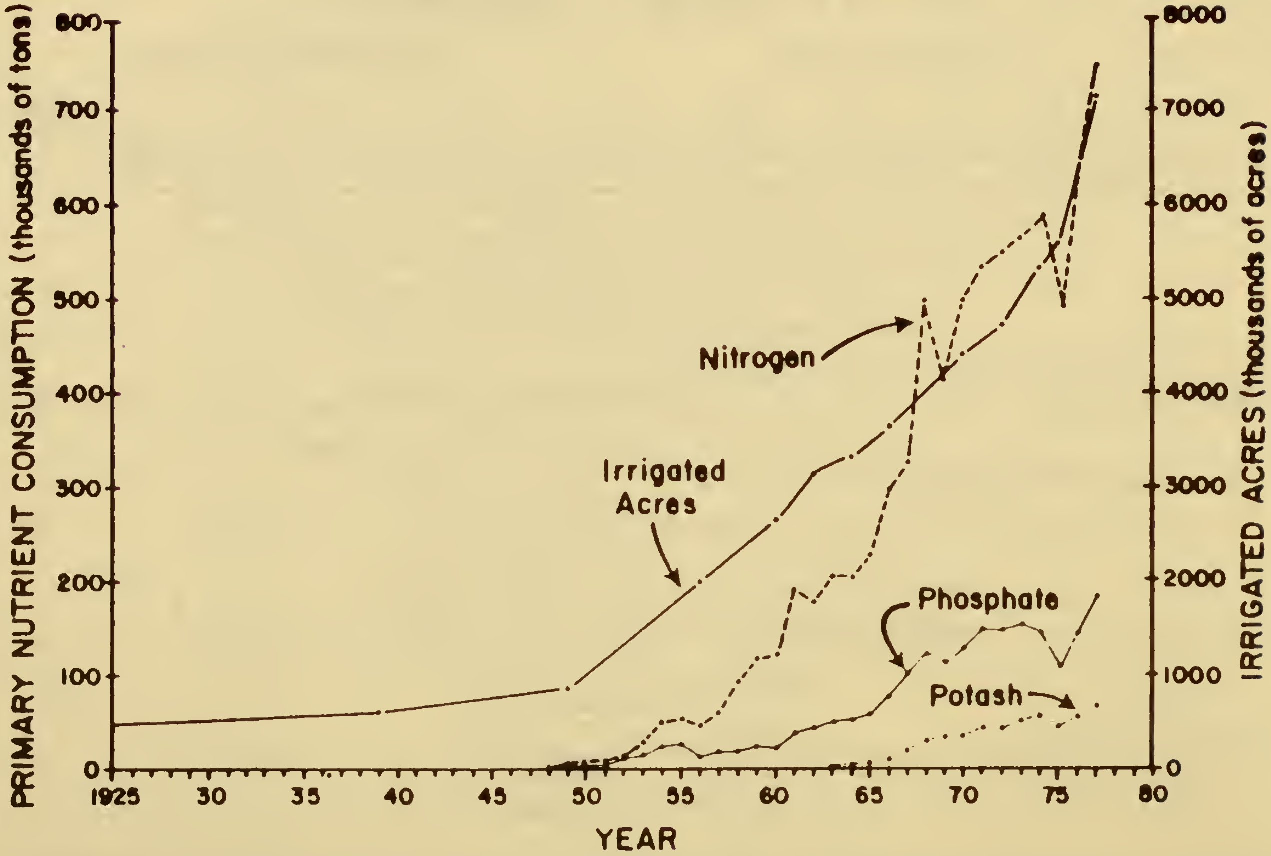


Figure IV-7



Primary Nutrient Consumption and Irrigated Acres in Nebraska. Source: U.S. Department of Agriculture and Paul Fischbach (Department of Agricultural Engineering, University of Nebraska-Lincoln)

Source: Donald A. Wilhite, Changing Fields, University of Nebraska-Lincoln: Institute of Agriculture and Natural Resources, 1979.

Figure IV-8.

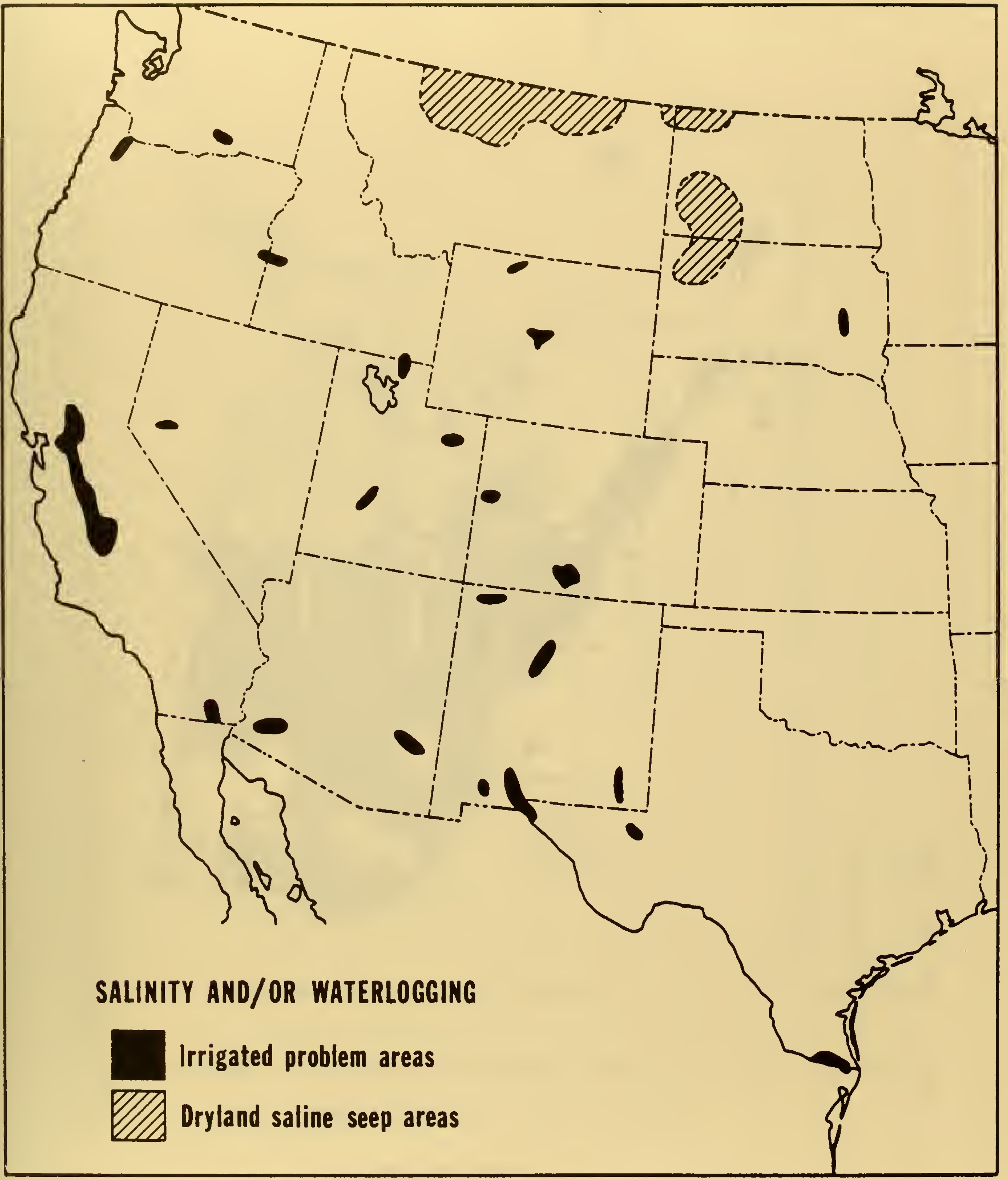
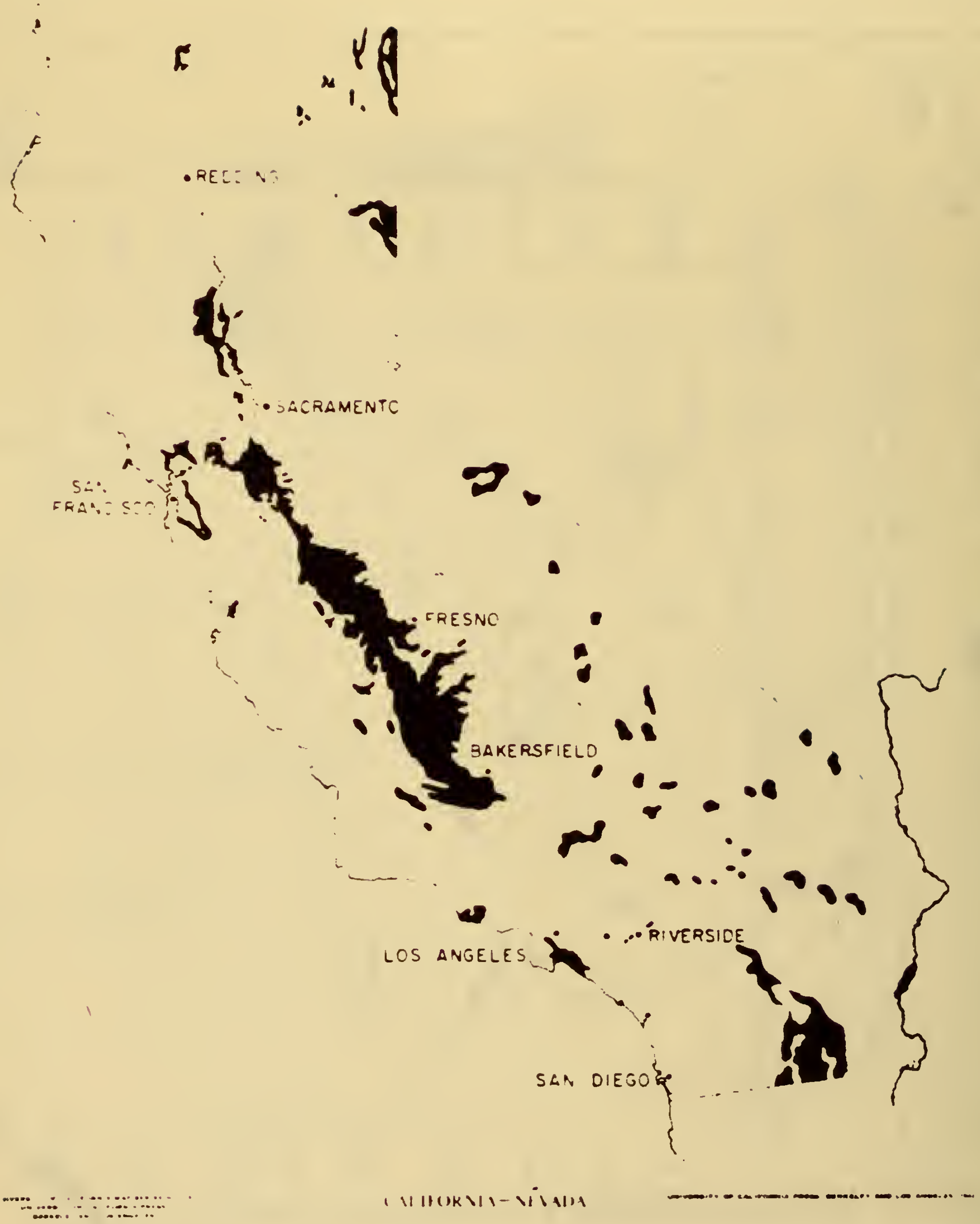


Figure 2. Salinity and/or waterlogging problem areas.

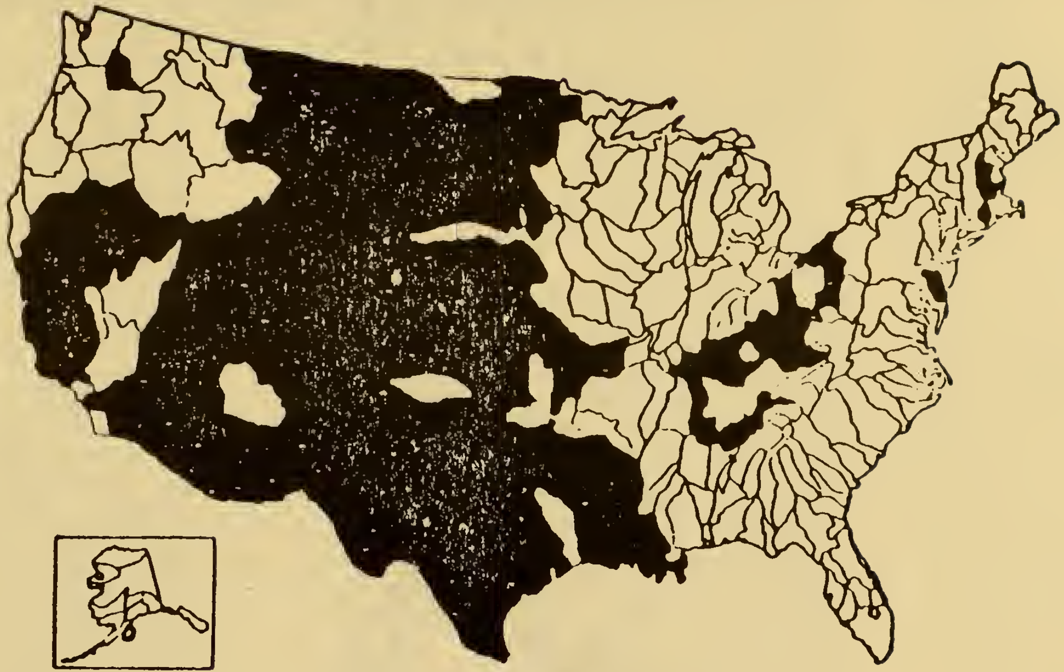
Figure IV-9



· DISTRIBUTION OF SALT AFFECTED SOILS IN CALIFORNIA
Published Soil Survey Reports

G.L. Huntington, 1969

Figure IV-10



Total Dissolved Solids

Pollution Problems - total dissolved solids from nonpoint sources

Source: USDA, RCA, 1980.

V. Factors Affecting the Desertification Process

Land Uses

This section examines the principal factors, both natural and human, that may affect desertification. The major land-use patterns in the Western and Great Plains States under private and public ownership will be discussed. See figures V-1 and V-2. It is to be emphasized that none of the described land uses and management practices is considered per se causative of desertification, and that the degradation of natural resources in many instances may be the product of a neglect of adopting normal safeguards.

As has been stated, desertification is the result of various ecologic changes that lead to soil depletion by erosion and nutrient losses, impoverishment of the vegetation and dependent animal life, salinization and waterlogging of irrigated and non-irrigated lands, degradation and exhaustion of water resources, and impairment and spoliation of land surfaces. Desertification may be spread by the hand of man along a desert edge, but far more generally it happens in patches over cropland and rangeland areas in arid and semiarid regions. It may also happen locally in overused recreation areas, mine land areas, and even uncared-for urbanizing areas. As seen elsewhere,desertification is already severe or very severe on over 155 million acres and moderate on 648 million acres in the U.S. It is like a malignancy, reducing the productivity and sapping the strength and beauty of the U.S. There are indications that it is steadily spreading in some parts of the country and that the rate of desertification may accelerate if development and management of natural resources in our arid/semiarid regions are undertaken without proper safeguards.

Farming

Loss of land productivity became a nationwide concern in the 1930s. The stage had been set a decade before, when an economic recession, coupled with extremely low rainfall in the northern plains, caused the abandonment of much Great Plains land broken for farming during World War I. Of the 70,000 to 80,000 people who had homesteaded between 1909 and 1918 in Montana, for example, 60,000 abandoned their farms by 1922. Much of this deserted plains acreage was still unprotected by permanent vegetation by 1930. Winds sweeping bone-dry, unprotected soil carried dust from Oklahoma, Kansas, and the Dakotas as far east as New York and Washington. Single dust storms dislodged and moved as much as 300 million tons of topsoil. Soil picked up from abandoned fields blasted and buried crops on still-cultivated acres, causing these lands to be abandoned in turn. See the crop loss figures for 1939 and 1956 in table V-1.

V.1

Since the Dust Bowl era, and particularly after World War II, American agriculture has become increasingly mechanized. The tractor replaced the horse, freeing millions of acres from pasture and fodder production for conversion to rowcrops. Since large, expensive equipment can be used profitably only on large acreages, preferably in a single crop, whole regions are in monoculture. The result has been trees and fences, with their attendant wildlife cover, coming down, and rowcrops replacing pasture and hay. These and other changes in agricultural technology have had some negative impacts that will be described below.

The number one wind erosion problem is the cultivation of sandy soils on the dry margin of the semiarid climatic zone. These soils are difficult to stabilize, as was accomplished to a considerable degree under the Soil Bank program of the 1950s. Rising grain prices and production costs and government urging to increase production have persuaded many farmers to again cultivate marginal lands. In 1974, about 140,000,000 acres (55,000,000 hectares) of land in the 17 Western States were used for dryland cropping. The rapid expansion of center-pivot sprinkler irrigation systems has occurred largely on erosion-prone sandy soils in the western Great Plains where the source of irrigation water is the Ogallala Aquifer. If or when pumping in those areas becomes uneconomic, the abandoned land will be ripe for greatly accelerated wind erosion.

The severity of wind erosion is dependent upon year-to-year fluctuations in weather. Approximately 4.6 million acres (1.8 million hectares) of cultivated land in the ten Great Plains States were damaged by wind erosion during the drought-parched winter of 1975-76 (October 1975 through March 1976) (Anon., 1976). This contrasts to the previous less severe winter in which 1.7 million acres (1.1 million hectares) were damaged by wind. Hagen and Woodruff (1975) calculated that particulates suspended in dust storms in the Great Plains during the 1950s and 1960s ranged from 37 to 551 million tons annually. Because of increased rainfall, the average dropped from 244 million tons in the 1950s to 77 million tons in the 1960s. Wind erosion produces a larger mass of particulates in the air over the United States than all other primary sources combined.

While one erosion control practice has been losing popularity, another has been gaining. Shelterbelts (windbreaks), though effective if managed properly, have become less acceptable in the 1960s and the 1970s than in earlier years. The main reasons are that they usually occupy land that could be cropped and they interfere with the operation of center-pivot irrigation systems and larger equipment. On the other hand, minimum tillage and no-tillage practices have been gaining popularity. These tillage systems keep stubble on the land to effectively protect it from wind and water erosion.

Table V-2 and figure V-3 show that the U.S. irrigation acreage has incresed by over 6½ million acres in the past 50 years. The increase in irrigated agriculture has resulted in increased short-term production, but in some

V.2

areas long-term detrimental effects related to desertification such as soil waterlogging and salinization as well as aquifer depletion have also appeared.

Water erosion is an ever-present hazard except on very coarse-textured soils. It is present on the steep slopes of the wheat lands in the Palouse region of the Pacific Northwest and on the shale-derived soils of the Dakotas, Wyoming, Colorado, Utah, and New Mexico. Virtually every medium-to-fine textured cultivated soil having a slope greater than 1 percent is subject to water erosion. When slopes become steep good land management can retard erosion, but can keep it within tolerable limits only with difficulty.

A 1977 report to the U.S. Congress by the Comptroller General of the United States detailed the costs of soil erosion in a few areas of the U.S. and noted the limited progress that has been made in controlling the problem. Large sums of money expended for technical assistance and cost-sharing conservation programs authorized by Congress have not been able to achieve complete success in controlling this problem.

Erosion of farmlands has serious adverse effects on crop yields and on water and air quality. Atmospheric dust impairs human and animal health, ruins machinery, is responsible for highway accidents, and--when dust storms are bad--causes mental depression. Sediment in streams and lakes interferes with fish reproduction and survival, reduces reservoir capacity, and makes it necessary to dredge ship channels. Realistic costs of these kinds of damage are difficult to calculate.

Irrigated agriculture would seem to offer the solution to problems of arid land degradation. With irrigation, crop yields improve, erosion control is facilitated, new crops may be grown, and a more stable economy is possible than when there is complete dependence on natural precipitation. However, a price is exacted for that more favorable situation: the hazards of salinization and waterlogging are increased markedly. These hazards are associated with all irrigated agriculture and can lead to the destruction of agricultural productivity. Both processes have been described in a previous section.

There are no good data on the amount of salinized and waterlogged irrigated land in the 17 Western States. A figure of 25 percent has long been used for the amount of land affected seriously enough to reduce crop yields. The main affected areas are in the Colorado and Rio Grande watersheds, the Great Basin region, and the Imperial and San Joaquin valleys of California (figure IV-8).

The problem of waterlogged soils is not a recent phenomenon. Problems of waterlogging were encountered by prehistoric Indian tribes in southern Arizona (Skibitzke, 1963). They used brush dams to divert water into a canal system. The gradient of the canals was less than that of the streams, and the land became waterlogged. After several hundred years,

V. 3

their agricultural enterprise failed. Waterlogging is still a problem in irrigated agriculture, and it increases with the area irrigated. For the 17 Western States, the irrigated area has increased from just over 2.5 million acres (one million hectares) in 1889 to 35-51 million acres (14-19 million hectares) in 1977. The distribution of irrigated land for these 17 States is shown in table IV-23.

Salinization of dryfarmed land is said to be the principle soil problem of the northern Great Plains (Vander Pluym, 1978). The problem is referred to as saline seepage. Saline seeps are increasing in size and severity in the United States and across the border in the prairie provinces of Canada. About 2 million acres (0.8 million hectares) of dryland are severely affected by saline seepage (U.S. and Canada) and another 7 million acres (2.7 million hectares) are affected to a lesser degree. A survey in Montana showed that dryland saline seeps increased from 53,000 acres (20,000 hectares) in 1959 to 156,000 acres (60,000 hectares) in 1975. The economic impact of the salinity problem has not been assessed but the fact that more and more land is becoming affected has caused alarm.

Subsoil compaction on cultivated lands is common wherever tillage is done to about the same depth year after year. Breaking up the hardpan is done by varying tillage depth. Avoiding tillage when soils are wet is a preventive measure.

Soil crusting tends to increase with cultivation and overgrazing by exposing the soil to the impact of raindrops, which effectively destroys the original structure and may cause crusting, depending on the soil structure. High-frequency sprinkler systems have a similar effect on unprotected irrigated soils. As with soil compaction, data on the damage done by soil crusts are not available. It is obvious, however, that the problem is a significant one when a light rain can stop seedling emergence over large parts of a field (Dregne, 1980).

Grazing

Grazing does not cause desertification in itself. It is only when the carrying capacity of the land is exceeded by grazing, whether by livestock, wildlife, or feral animals actually grazing on the land, that overgrazing and desertification can occur.

Table V-3 and figure V-4 indicate that use has increased dramatically for cattle over the past 130 years in the 11 Western States. Current livestock production figures are presented in tables V-4 and V-5. In addition, BIA has over 7,430,000 total AUMs, located mainly in the Western States. Although is true that the range is in the best condition it has been in this century, it must be noted that prior to the turn of the century, overgrazing occurred so heavily that the range is still suffering from its effects. Very significantly, the overall range condition is still in the two lowest productivity classifications, as shown in tables V-6 and V-7. Grazing land by ecosystem is presented in tables V-8 and V-5 because the type of ecosystem reflects the potential productivity. Concentration of livestock around water sources also affects productivity.

In the 17 Western States, approximately 796 million acres (313 million hectares) of rangeland are grazed either part of the year or full-time. Water erosion, in particular, has been a serious problem since the 1800s, and, as stated, its effects still plague some of the grazing lands of the United States. An example of this problem can be found on the Navajo Indian Reservation. In the 1850s the Navajo were given "lush grass meadows" in Arizona and New Mexico (Van Voorthuizen, 1978) to settle upon with their sheep. At the time, Navajo herders migrated between summer ranges in the mountains and winter grazing in the valleys. They were nomadic, and put relatively little pressure on the land. As the number of people and livestock increased and their freedom of movement was restricted, grazing pressures became greater, with the result that today the land is seriously overgrazed, badly eroded, and of low productivity. Much of the Southwest has suffered severe desertification in a similar manner. The Agricultural Research Service (1974) has estimated that in 1972, 71 percent of rangelands in the 17 Western States were in only fair to poor range condition (table IV-7). In 1976 USDA (RPA, 1979 draft) found 53% of the grassland ecosystems, and 55% of the shrubland ecosystems of the U.S. rangelands in low to moderately low conditions. Comparisons of those two years (and trends) are difficult to discern since the classifications used were different from each other.

Many gains have been made in range management in the past 50 years. Use of rotational and deferred grazing practices, herbicides to control weeds, and aircraft to seed overgrazed areas have shown the way to range improvement and increased meat production in the arid regions. Ranchers, due to economic reasons, are tempted to run as many livestock as the land will bear, taking the risk of overgrazing. But during periods of drought, the desertification hazard intensifies. ?

In general, the animal grazing units must be kept in approximate balance with the land's carrying capacity. During drought years, the use must be decreased so as not to cause extensive deterioration of the land, but this practice is generally costly in terms of direct losses, and in time and investments needed for restocking the diminished herds. An alternative to reduced use during drought periods is buying feed or renting of additional pasturage.

Rangelands exposed by trampling and overgrazing are especially vulnerable to erosion as are areas with limited cover; fine-textured, easily dispersed soils; and sloping terrain (table V-6a, figures V-4a and V4b).

V-5

Range soils experience surface compaction and crusting by the hooves of animals. Some compaction occurs whenever livestock graze an area but the effect is much more pronounced when the land is overgrazed and has little vegetative protection. The absence of vegetation cover enhances soil crusting and compaction, which in turn increases runoff and reduces water intake, which further reduces herbage production and progressively increases the runoff and compaction hazard. As Rauzi and Fly (1968) noted, water intake rate, range condition class, and herbage production on rangelands tend to vary together on a specific type of range site. Range soil compaction is also a function of the vegetative cover, type of soil, and numbers of livestock, and in general improving the vegetative cover helps to control the problem.

Soil compaction, by increasing runoff, increases in turn both erosion and downstream flooding. Documentation of the amount of damage resulting from compaction alone is not available. The extensiveness of the problem in arid regions indicates that the environmental impact should be large in the aggregate even though relatively small on any one field.

Wildlife may impact an arid site adversely when some segment of the animal population increases beyond the carrying capacity of the system, e.g., when a natural predator disappears from the area or when we feed elk artificially. Interspecific competition--the potential conflict between two species that require the same resource--will be discussed in another part of this section. This type of competition, and adverse impact on ranges, may be produced by feral animals such as wild horses and burros.

With the passage of the 1971 Wild Free-Roaming Horse and Burro Act (Public Law 92-195) the Secretary of the Interior, through the Bureau of Land Management, was charged with the protection, management, and control of all unbranded and unclaimed horses and burros inhabiting public lands. Congress specifically states these animals are to be considered as an integral part of the natural system of the public lands and would be managed in such a manner as to achieve and maintain a thriving natural ecological balance.

Wild horses and burros are now far from being vanishing animals. Since the passage of the Act, free-roaming horses and burros have been increasing and present estimates number them in excess of 65,000. The population density of wild horses and burros, like that of any other animal, must be in tune with and not exceed the carrying capacity of the available habitat. Other than this general observation and the limited data that Hall (1972) and Feist (1971) collected on the Pryor Mountain horses, there is no scientific information available on optimum population levels, the results of overcrowding, competition, or the effects of a degrading habitat.

Population Distribution, 1978

	Horses	Burros
Arizona	70	3,780
California	3,700	3,845
Colorado	990	-
Idaho	1,200	10
Montana	300	-
Nevada	31,800	1,420
New Mexico	70	25
Oregon	4,050	-
Utah	2,150	80
Wyoming	9,700	-
	54,030	9,160

Both the U.S. Forest Service and the Bureau of Land Management are developing plans for protection, management and control of wild horses and burros. Both agencies have land use planning systems that are evaluating the vegetation and watershed conditions, wildlife needs, livestock use, recreational use, and other legitimate demands. Management plans will establish the maximum number of animals for specific herd areas, and where adequate space, water and forage will be allocated.

Desertification impacts wildlife as well as it does livestock. The deterioration of soil and water quality, the decreased availability of food, water, and cover, and in general, an impaired habitat, do not provide the necessary conditions to maintain a healthy, balanced, and/or adequate population of animals.

The reduction in production caused by degraded range represents a loss of 30 to 40 million AUMs of grazing, or a loss of 6 to 8 hundred million pounds of red meat and a significant amount of wool, mohair, leather, tallow, insulin, and many other byproducts from animal carcasses (RCA, 1980).

A wildlife habitat classification of BLM rangelands in 1975 (table V-9) indicates that about 60% of wildlife habitats are static, about 30% are declining, and only about 10% are improving. Much of the blame for this deterioration and failure to improve can be placed on the many processes of desertification.

V 7

Mining

Desertification is not limited to agriculture. Mining, particularly surface mining, has already impacted thousands of acres of land in the West. The visual impact of unsightly piles of mining waste is far out of proportion to the land area involved. Until the postwar years, about the only large open pit mines were copper mines. The other mines were of the shaft type, where waste heaps were relatively small and confined to the area around the mine opening. Since World War II, huge uranium and coal surface mines have been developed, most of them in the Rocky Mountain states from Montana to New Mexico. When oil shale mining begins on a commercial scale, land will be further affected, but for the immediate future the principal environmental challenge will be surface coal mines in the dry climate.

Open pit mining desertifies by (1) stripping the land of its protective cover against erosion or (2) accumulating waste rock and mine tailings on the land surface (Day et al., 1977). The solution to these problems, though similar, is not exactly the same. The problem of revegetation of disturbed lands is exacerbated by the lack of adequate moisture for germination and maintaining the erosion-abating ground cover. The reclamation of tailings is a very difficult and costly task. At best, tailings are not esthetically pleasing. At worst, they erode or pollute badly or are biologically sterile. The best treatment is to stabilize them with vegetation as rapidly as possible. Rehabilitation of mined land has been estimated to cost $5,000 or more per acre (LaFevers, 1978).

Surface coal mining in the northern Great Plains and Rocky Mountain states will take more land in the near future, estimated to be at least 92,000 acres (37,000 hectares) by the year 1990 and 200,000 acres (78,000 hectares) by 2000 (NAS, 1974). If coal gasification is done on a large scale, surface mining will have to expand even more rapidly.

The Public Land Law Review Commission found that the public land areas of the West generally hold greater promise for future mineral fuel and non-fuel discoveries than any other region of the country. It is in the public interest to acknowledge and recognize the importance of mineral exploration and development in the public land legislation.

The existing laws treat mineral exploration, development, and production as distinct activities outside the mainstream of the land use planning and management process, although minerals and nonmineral resources are both part of the land, and decisions, policies and actions affecting each inevitably affect the other.

Historically, though, mineral uses have been preferred over nonmineral uses of federal land that is open to mineral activity. Mineral rights,

V.8

once acquired, override all nonmineral resource values. Neither the mining nor mineral leasing laws contain incentives or other mechanisms adequate to ensure proper balancing of mineral and nonmineral resource values. Many provisions, especially in the Mining Law, result in adverse impacts on nonmineral resources without contributing to efficient or diligent mineral activity (OTA, 1979). However, stipulations can be placed in the leases.

State regulations on restoring mined land to a condition of equal or greater potential productivity than it was before mining occurred has stopped the blighting of landscapes that accompanied mining in earlier days. Old abandoned mine sites, however, have been left to nature, and nature has difficulty coping with mine wastes in the arid regions. Their restoration will depend upon state action in cases where the land is now of little value. Where states do not have reclamation requirements, mine operators decide whether their waste areas will be rehabilitated.

As it is with other land uses, improving disturbed surfacing mining areas becomes more difficult as the climate becomes drier. Revegetating an area in western North Dakota is easier than doing the same thing in northwestern New Mexico. Research has helped find solutions in some cases, but serious problems confront efforts to reclaim land in the arid southwest. Irrigation and fertilizer can assist greatly in establishing a plant cover. However, the viability of the vegetation when irrigation is stopped cannot be predicted with assurance. It is no small task to improve overgrazed rangeland in arid climatic zones; revegetating mine spoils in a short span of years may be nearly impossible without irrigation.

Energy Production

The production of energy, through fuel processing and power generation, may have a direct impact on the agricultural and ecological productivity of the Western and Great Plains drylands. Assuming that the mix of domestic energy in 1990 includes 1.24 million barrels per day of synthetic fuels derived from coal, about 25 plants would be needed. In the West, about 500 square miles of land would be strip mined over the 30-year lifetime of the plants. If the energy mix also included 400,000 barrels per day of synfuels from shale, about 100 to 200 additional square miles would be required (CEQ, 1979).

These large tracts of land do not include the land that is indirectly disturbed by the associated exploration, construction of roads, water facilities, settlements, etc. These uses are estimated to be three times the direct areal disturbance. A total of approximately 2,500 square miles of land disturbed can be expected. This is an area larger than the state of Delaware.

V.9

Constraints on energy development will primarily involve competition by agriculture and conflicts with environmental goals, plus the differing economic goals of the region's exporting and importing energy.

Since there is a direct relationship between land productivity and water, some of the factors that affect energy, the renewable and the nonrenewable resources of the drylands will now be discussed. When compared to the 5.97 million acre-feet per year (7.4 billion m^3/yr) unallocated and available in the Missouri River (measured at Sioux City, Iowa) in low water years, one can conclude that there is more than ample water to meet all future needs in the basin in the year 2000 (ERDA, 1976). However, the total water consumption of the synfuel industry outlined above would be enough to irrigate roughly 100,000 acres of agricultural land per year. This much water may be physically available in the West, but it may already be committed to other purposes. New towns to house plant workers will put further pressure on water supplies (CEQ, 1979).

And while there may be ample water on a multistate basis, the local occurrence of water does not match the distribution of coal and lignite in these states. As a result, on a local and regional level, there may be severe water shortages and shortfalls unless new storage facilities and aqueducts are built to redistribute the water. Such redistribution could often involve existing federal water storage reservoirs constructed by the Water and Power Resources Service (WPRS). However, nonagricultural use of water in these reservoirs is being challenged because the WPRS' enabling legislation specifies that its work should benefit agriculture.

Condenser cooling--the major use of water in coal production--and steam electric plants of a given size and efficiency using wet cooling towers, have similar water requirements whether fueled by coal, oil, or gas: about 10 million gallons per day (mgd) per 1000 MW. Flue-gas desulfurization units add about 1 mgd to this amount for coal-fired plants. A nuclear plant of this size requires about 17 mgd.

An oil shale industry also requires water at several points: to mine it, to retort it, to revegetate the spent shale, and to quench the thirst of the humans hired to work it. Rough estimates see the need for two or three barrels of water for every barrel of oil extracted. There is uncertainty about just how much water will be needed to keep the spoils from blowing away and to persuade plants to grow on them. The National Petroleum Council's Oil Shale Task Group pegged water needs at 16,000 acre-feet per year for each 100,000 barrels per day of capacity; this is just for mining, retorting and upgrading through refining (Bowden, 1975).

The manufacture of natural gas is a hydrogenation process in which water is the source of the hydrogen. There is a need for a little over

2 million gallons per day for a plant manufacturing 250 million cubic feet per day of synthetic natural gas (Probstein, 1979).

A 1974 National Academy of Sciences study concluded that water was available for rehabilitating most of the coal areas of the West. The study found that the major water requirements for rehabilitating surface-mined areas were: (1) supplemental irrigation of vegetative plantings on reshaped spoil piles; (2) on-site consumptive use of water on stockpiles of topsoil and mine spoil banks where interruption of surface flow causes internal drainage; (3) permanent irrigation on rehabilitated mine lands; and (4) alternative water supplies to replace those diminished in quantity or quality by mining activities. The amount of water needed to keep down dust during the mining process and minimize wind erosion on the stockpiled soils is not great. Nor is the amount of water needed for establishing native plants. Although the necessary quantity will vary with landscape, exposure, soil properties, and climatic factors, there are few areas where the small amount of water needed during the establishment phase will not be available. Water availability, however, should be determined before mining begins (Box, AAAS, 1975). Although some success has been demonstrated, there has not been enough time to insure that the new vegetation can survive without continued human care.

The major problem associated with rehabilitation of oil shale areas is salt management. In any above-ground retort process, large amounts of spent shale will be deposited on the earth's surface. This retorted shale is high in salts, usually too high for most plants to grow well. Schemes for rehabilitating this salty material require, first, that the salt be contained and not allowed to escape into the watershed or drainageway and, second, that the salts be separated from the root zone of the vegetation planted for rehabilitation.

The most common way of removing salt is leaching it from the upper layers of the spent shale. This requires constant heavy applications of water to wash the salts deeper into the pile (Box, AAAS, 1975). Revegetation of spent shale has not been successfully demonstrated on a large scale and over a long enough period to be certain that it can survive after human attention wanes. Disposal and reclamation of spent oil shale is a critical environmental factor and unless carefully managed could contribute to additional barren and unproductive land.

Restoration of mined lands is an issue that has stirred the national consciousness and has resulted in the passage of federal and state strip-mine reclamation laws administered by OSM. Because of this and the likely focus of future strip mining activities in the arid West, reclamation of mined lands is a critical factor in the development of any synfuel production (ERDA, 1976).

Urbanization

Urban development in the arid zone is not a recent phenomenon. However, interest in this land use is high because urban growth is especially rapid in the Western U.S. A net migration between the rural and urban areas is occurring in the Western U.S., as well as from the Snow Belt-Eastern U.S. to the Sun Belt-Western U.S. The result of these movements is an increase in the urban and suburban population of the 17 Western States.

Land use regulation in the desert Southwest seems to be minimal in comparison to other U.S. regions. Attempts to optimize urban development through governmental regulation may be politically difficult since many residents of this area have moved to it in part because they perceive it to impose fewer restrictions on their activities (Innis, 1978).

Another problem is that newcomers from more mesic regions are unaware of the constraints under which arid and semiarid systems function. Desert cities have special problems such as their extreme radiation environment, water needs, and tendency to be under pollution-prone descending air masses. The perception of these systems' limited carrying capacity is masked in many instances by the pleasant climate and the availability and use of technologies to overcome certain limitations, e.g., through water transfers and groundwater pumping. The limits to which these manipulations can be safely and economically applied are usually not well realized.

Urban sprawl creates specific problems. Subdivision development accelerates rates of erosion and creates problems of downstream deposition in these rapidly developing urban areas. Disturbed soils are susceptible to erosion and mass movement due to bare ground exposure. Highway construction also causes problems due to lack of early stabilization of cuts and fills in many areas. Urban and built-up areas are susceptible to accelerated erosion for a 3-5 year period.

The remarkable change of the last decade, with the highest rate of U.S. population growth now occurring in rural and semirural areas for the first time in our history, may create development pressure on farmland in new areas. Especially affected by this trend is the Southwestern U.S. If we consider that U.S. exports account for 52% of the wheat and feed grains traded in world markets, much of which is produced in the Great Plains and Western States, the loss of prime land to other uses is highly disturbing. Not only is the agricultural land being converted impacted, but also the bordering farmland, which may be more easily affected by erosion, runoffs, and salinization than it was before conversion. This particular change is of special concern since in general it is the fertile flatland with water available that is taken by urban sprawl. The SCS estimates that about 80% of the available cropland in the U.S. is currently being cultivated. The other 20%

V.12

can be converted to cultivation, but not all is of the same quality. Losses of productive acreage can have a severe impact on current and future agricultural activities. It has been estimated that for each acre removed by urbanization, another acre is surrounded and isolated as well, thus effectively removing twice the developed area. The SCS estimates that each year approximately 10 million acres disappear from the rural land reserve (Little, 1979). This figure does not include the acreage under impending urban expansion.

Figure V-6 shows by region land with a high, medium, low, and zero potential for conversion to cropland based on the 1974 price-cost data. Note the relative scarcity of high and medium reserves in the regions which are losing prime farmland most rapidly--the Northeast and Pacific especially. Here reserves are equal to or less than the amount of prime land which, at present rates of loss, will be converted to other uses within 10 years (CEQ, 1978).

The growth of localized population and other activities in the Western States has been accompanied by a deterioration in local and regional air quality, which in turn impacts the ecological balance and the crop production of the affected area. But the major problem is the demands imposed on water supplies that have often forced agricultural lands to be retired either to housing or for the acquisition of water and groundwater rights (Johnson, 1977). Reductions in the groundwater levels and quality have resulted in increased costs and energy consumption for pumping and treating in many places.

Arizona and the Tucson area particularly are excellent examples of changes in settlement patterns. In the last ten years, Arizona's population has increased by 630,000 people and by 1974, 75% of the total population lived in Phoenix and Tucson and their suburbs. See figures V-7 and V-8. This urbanization is reflected in the patterns of income. In 1927, 14% of the total income was from agriculture and 14% from mining. By 1960, however, only 7% was from agriculture and only 4% from mining. The recent influx of people to Arizona is based on the increase of light industry, defense-related projects, recreation, and retirement communities there. The stresses of development, in combination with the normally occurring periods of drought, has resulted in localized soil erosion, permanently dried-up streams, deterioration of perennial grasses, the invasion of undesirable plants such as mesquite, and the decrease in water supply. In summary, this rapid growth, if not carefully managed, may prove to be a drain on the resources of a fragile environment (Langford-Smith, 1978).

Recreation

This section draws heavily on USDA Renewable Resources Planning Act and Soil and Water Resources Conservation Act documents now in draft form (prepared during 1979-1980) and on the 1979 CEQ-commissioned report, "Off-Road Vehicles on Public Lands," by David Sheridan.

Recreation is a factor affecting desertification, since some types of recreation may lead to it and, in turn, desertification may impact the recreation industry, which is becoming very important in the economies of arid and semiarid areas.

A wide spectrum of outdoor recreation opportunities in a region is available only if all the lands open for outdoor recreation provide both a diversity of types and levels of development and space to separate conflicting uses. There are, however, limits to the spectrum of opportunities that can be supplied.

The 1977 National Outdoor Recreation Survey shows significant differences between participation in recreation in various regions of the country. More westerners participated in camping, backpacking, and skiing than did residents of other regions. Table V-10 reveals the large extent of participation in outdoor recreation activities nationwide: these figures are expected to increase over the coming years, as shown in table V-11. In 1977, over $11 billion was received for amusement and recreational services, with construction of buildings for social and recreational purposes that year amounting to $3.5 billion nationwide. In general a very large share of these activities take place in the Mountain, Southwest, and Pacific regions. Many of these recreational activities take place in publicly owned recreational services including state and local parks and the National Park Service sites. The Bureau of Land Management alone administers 326 recreational sites covering 12,196 acres and having an estimated 58,308,000 visitor-days use in 1976, mainly in the Western States.

Although recreation has not been a major use of rangelands in the past, such use is increasing rapidly. Construction of new recreation areas, especially for off-road vehicle areas, can severely reduce an area's grazing potential because of vegetation removal, soil erosion, effects on livestock and wildlife, damaged range improvements, and competition for water supplies. Often, prime land for recreational activities is prime rangeland; and dispersed recreation, where controls on recreation are least, creates a significant problem in rangeland administration.

In order to make better use of the recreational opportunities available throughout the arid/semiarid areas of the country, we need to develop better measurement techniques for dispersed recreation activities; to identify types of use, expectations, and behavioral patterns of dry area recreationists; to identify and evaluate the relationship between environmental/ecological changes and recreation activities/use patterns; the relationship between values and user conflicts; and the relationship among users from a human ecology perspective (Innis, 1978).

In the last few years off-road vehicles (ORVs) have gained greatly in popularity, specially in the arid/semiarid areas of the West.

Motorized recreationists represent about 25% of the U.S. population. All together there are at least ten million ORVs in the United States today, including:

- about 8.3 million motorcycles of which 5.4 million were used off-road at some time;

- about 250,000 dune buggies; and

- about 3 million four-wheel drive vehicles, of which about half are regularly used for off-road driving.

One drawback is that ORVs have a major impact on the relatively thin layer of soil in arid and semiarid areas, and in turn on local flora and fauna. There seem to be two basic soil responses to ORV use. First, the sandy and gravelly soils susceptible to direct quarrying by ORVs, when stripped of vegetation become vulnerable to rapid erosion processes--usually by rill or gully erosion. Near Santa Cruz, California, for example, ORV trails used for about 6 years are now gullies 8 feet deep. Second, the more clay-rich soils that are less sensitive to direct mechanical displacement by ORVs, exhibit rates of erosion of stripped clay-rich soil much higher under ORV user than under natural conditions. Furthermore, ORV pounding of clay-rich soil causes crusting and compaction, thereby reducing the infiltration of water. This in turn leads to greater rainwater runoff, which causes gullying lower in the drainage. Also, there is much less moisture available to nourish plants and far less water gets through to replenish the groundwater supply. Once topsoil has been stripped away, the regeneration of it may take many years, depending on conditions. Even under optimum conditions, it may take nature 500 years to generate an inch of topsoil, and some soils are so old that their character was formed by climatic conditions which no longer exist, making them practically irreplaceable.

In flat, dry areas ORVs expose the soil to another powerful erosional force--the wind. In addition, the subsurface soil experiences greater temperature extremes--becoming hotter during the day and cooler at night than it would under normal conditions. ORVs may also destabilize sand dunes, making them more vulnerable to wind erosion. Destabilized inland dunes spill into adjacent nondune areas, and windblown sand from them covers land well beyond the area of direct ORV impact.

In damaging vegetation by direct contact, ORVs also affect animals, whose food and shelter is heavily diminished. Most naturalists think that when wild animals are displaced from their natural areas because of destruction of vegetation, or noise, the survival of the displaced individuals is precarious. Or, as they succeed in reestablishing themselves in other suitable wild areas, they may displace resident individuals whose survival chances are then greatly reduced.

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Multiple-Use Competition for Resource Base

Competition for natural resources between uses and/or users may result when more than one maximum use, or the overuse of a limited resource base, takes place in an area. Some aspects of multiple-use competition that will be discussed are the physical availability of resources, and the conditions that may influence the onset and outcome of competition. Throughout this discussion it will be recognized that two extremes in the usage of the natural resources of an area are, on one hand, the ban on use, resulting in total preservation, and on the other, the total use of resources, resulting in depletion and probably irreversible damage to the area. In between these extremes a whole gradient of development/use/conservation mixtures can be found. Depending on the value of the resource, the benefits accrued from its use, the extent of the damage to the area, if any, the cost of rehabilitating the site, among other economic considerations, recovery may be left to the natural processes or could be speeded up through artificial repair. More importantly, these considerations may influence the selection of types and combinations of uses, number of users, and conservation measures.

Among the special characteristics of arid/semiarid lands, the limited availability of water, natural habitat, and forage, and some of the interaction between some main land uses, will be presented in the following subsection as examples of competition for the resource base.

Availability of water and competition: Water in sufficient quantity and of sufficient quality is the basic element of life. The competition for water in the arid and semiarid Western States has always been strong but is now increasing rapidly as human and animal populations, and industrial, agricultural, and recreational uses grow. As the water supplies of the Western U.S. are strained due to increased consumption and pollution, it is probable that less will be allocated to agriculture, and more will go for domestic and industrial use. See figures V-9 and V-10. New irrigation systems may not significantly contribute to arid land settlement for long, and the changes in land use that may follow could negatively affect the quality of the land.

In the U.S., 10 percent of the developed cropland (or 42 million acres) are irrigated (see figures V-3 and V-11 through V-13). During 1975, 50 bgd (billion gallons per day) of ground water were used for this purpose, representing roughly 40% of the total fresh water used for irrigation in the country. Taking into account that agricultural exports are in the range of $20 to $25 billion per year, with particular interest in specialty crops, it is evident that any detrimental change in the supply of the water and the conditions of the soil needed to maintain such activities could have serious consequences. On the other hand, in the U.S. today 7.5 bgd of water, or 2.5% of all withdrawals, are used by minerals industries (metals, nonmetals, and fuels), and water withdrawals for fuel mining and processing constitute about 36% of the total withdrawn by the mineral industry, but the consumptive use is 62% of the total mineral mining water consumption. The coal and oil shale mining and processing are and will be mainly located in arid-semiarid regions, a very important one being the Upper Colorado region, creating heavy competition between this and other interests for the allocation of water resources. In 1975, ground water constituted over 40% of the total fresh water withdrawals (approximately 82 bgd) and water mining is increasing at an accelerated rate, largely due to agricultural and settlement uses. During that year overdrafts in the Texas region alone amounted to 78 percent of the withdrawals, 50 percent in the Lower Colorado region and 30 percent in the Rio Grande region. In central Arizona ground water levels are declining from 7 to 10 feet per year. The future facing these regions is indeed uncertain, given the high probability of rapid ground water depletion, even if the rate of water mining is maintained at the present levels. This can certainly affect the quality of the land and future land uses.

Aside from the expected population growth in the U.S., an internal migration from the snow belt to the sun belt is occurring also at an increasing rate, with a popular preference for the dry, warm climate of Central and Southwestern States. One impact of this trend is that a projection for the year 2000 is of an increment in water withdrawals and in the water-consumptive use of up to 50% of the 1975 values for the Colorado, California, Rio Grande, Great Basin and Texas Gulf regions. Today the total freshwater withdrawals in these regions are between 80 and 90 bgd, representing 26% of the total withdrawals in the nation, 60% of which comes from surface water (table V-12 and figure V-14). The projected more-intensive use and reuse of the available surface and ground water supplies present quality problems that will become critical, requiring growing capital outlays and improved technology to solve. It is estimated that by the year 2000, there will be a deficiency in water supply for California's urban and agricultural demands totaling over two million acre-feet per year (Gertsch, 1977). These figures show in some measure the intense interaction between the water resources of arid-semiarid regions, other natural resources, human activity, the far-reaching consequences of changes in the existing water supply-demand system, and the probability of desertification. Instream flow uses can also compete between themselves and inadequate instream-flow may adversely affect recreational activities, hydropower generation, navigation, waste assimilation, and aquatic life. Such low flows can be caused by excessive depletion, diversion, and operation of reservoir storage for offstream project purposes such as irrigation, thermal power generation, export to adjacent basins, municipal and industrial water supply, hydropower peaking and flood management.

These uses may affect the hydrological cycle in the area and in turn its carrying capacity. Similarly, the diverse uses that riparian systems can be put to may have completely different consequences and while riparian ecosystems throughout the Western United States are limited in size and scattered, their ecological importance merits special attention.

A riparian ecosystem consists of the stream and streamside flora and fauna which may lace its way through a very different type of environment. Dryland riparian ecosystems are extremely important, highly productive linear oases in the surrounding arid areas.

Riparian ecosystems provide soil and water resources for irrigated agriculture and livestock production in regions where the moisture regiment and carrying capacity would not otherwise provide them. Recreational uses of riparian ecosystems are also important, with fishing, canoeing, birdwatching and other activities dependent on the stream. In general, dryland riparian systems facilitate the exploitation of the adjacent uplans, thus enhancing the productivity of neighboring arid areas. This type of ecosystem often contains the only large vegetation species, such as cottonwood trees, in areas where grasses and shrubs predominate.

For wildlife, riparian ecosystems provide food, water, shade, cover, and migration corridors for both resident and migratory species. Further, amphibians and fish depend directly on the quality and quantity of the water in the system. When unrestrained use or overuse diminishes the quality of or destroys a riparian system, local desertification may set in.

Floods and flood control: When the upper reaches of a river basin lose their vegetation through deforestation and desertification, the risk of floods downstream increases several-fold. As described in Section IV, unprotected soils are eroded and transported away by wind and water, specially by storm water. A description has also been given of how, when drylands are desertified, storm runoff increases due to lowered infiltration soil capacities. This runoff can become torrential, and the intensity and velocity of flash floods also increases.

Flash floods are a normal feature of arid and semiarid lands, as are droughts, and are produced by highly localized and intense rainfall. The geology, topography and drainage of the watershed, together with the amount and quality of the existing vegetation, influence the conditions under which flash floods occur.

Another consequence of the increased runoff and erosion of desertified hydrologic systems (watersheds, playa lakes) is the increased amount of sediment entering the surface water bodies. This in turn results in siltation, as described in Section IV, with several detrimental consequences.

Some flood control measures can unfavorably impact watersheds, specially small ones, by the channelling of streams. The meandering streams are straightened, and the biomass of riparian vegetation is thus effectively reduced. Often in channelling, the streambeds are lined with concrete or other impermeable materials which prevent water seepage. The riparian vegetation is strongly impacted, sometimes irreversibly, desertification sets in, and the whole cycle of more runoff, more erosion, more sediment, higher water volume downstream, is set in motion.

Availability of natural habitat and forage, and competition: The interaction in which two species require the same resource is called interspecific competition. Two species can use a common resource without necessarily competing. Competition takes place only where the resource is used to the point of being in short supply, and the populations are affected as a result.

The actual feeding patterms of animals are complex, varying with geographic location, time of year, and plant subspecies. See figure V-15. Competition is least likely to occur between two coexisting species with very different feeding niches. Two herbivorous species which would not compete significantly in a system with healthy, diverse vegetation might converge in their feeding patterns where vegetation is degraded and would be driven to competition. Competitive effects are not confined to food. If one animal eats vegetation needed by another for shelter, the detrimental effect is just as real as food shortage.

The most dramatic effects are those in which the major life form of the native vegetation is changed, as when grassland is converted to shrubby vegetation. For example, pinyon-juniper forests have invaded grass-covered foothills of Western mountain ranges; sagebrush and shadscale have replaced perennial grasses, forbs, and more desirable shrubs in the Great Basin valleys and plains; and creosote bush desert has replaced grassland in the Southwest. Such vegetation changes have probably the more profound effect on some wildlife species. However, there may be some species for whom the vegetation changes are beneficial. In the case of two noncompetitors, range degradation for one may be range improvement for the other. This is an area that needs to be better understood, specially taking into account that various livestock and wildlife species are specialized to a degree in their feeding patterns, each applying different kinds of pressure on the local vegetation. If competition occurs in detriment of the quality of the land, the probability of desertification is enhanced.

Multiple-use management: Multiple-use has been defined in P.L. 94-579, cited as the Federal Land Policy and Management Act, as the management of land and resources "so that they are utilized in the combination that will best meet the present and future needs of the American people; making the most judicious use of the land for some or all of these

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resources . . .; the use of some land for less than all of the resources; a combination of balanced and diverse resource uses that takes into account the long-term needs of future generations . . .; and harmonious and coordinated management of the various resources without permanent impairment of the productivity of the land and the quality of the environment with consideration being given to the relative values of the resources and not necessarily to the combination of uses that will give the greatest economic return or the greatest unit output." (emphasis added). This last part is what essentially differentiates public (federal, state, and local) from private standpoints, as will be discussed later in this section.

Multiple-use management is a difficult task to undertake under any circumstances, at any level of stewardship, and under any type of ownership. It is specially so, given the limited knowledge available about the interrelationships, the relative values, the costs, and the benefits attributable to the various combinations of resources and their uses that comprise different management schemes. It is even more complicated where the ecosystem to be managed is short of at least one main resource: water. Nevertheless, manage we must, to the best of our ability and understanding.

Land Ownership and Land Stewardship

Table V-13 shows the approximate acreage of land by ownership and by State. Some states, especially Nevada, have a large portion of their land managed by the federal government (table V-14). In others, such as Texas, land is mostly privately owned. Arizona has the largest percentage in state ownership. Figure V-16 shows land ownership by region.

Changes in land use have led to some land ownership changes, such as the purchase of land by federal, state, and/or local governments for streets, highways, parks, government buildings or the sale or exchange of land by federal, state, and local governments to the private sector. The changes occurring in the last few years have generally not been large enough, in terms of acreage, to significantly alter the approximate figures presented in these tables.

Throughout the seventeen Western States, 36% are federal lands, including Indian trust lands; 5% are owned by the state; and 59% are in private ownership. This fact, plus the areal "checkerboard" condition of these lands, produces a situation in which the kind of management used in land of one type of ownership directly or indirectly influences the others.

Land ownership also determines the stewardship employed: the purpose of use, the use itself, and the methods applied to fulfill the purpose. Privately owned lands, when they are used, must provide shelter, a profit, and support a livelihood. State-owned lands provide financial support for the school systems, and serve as facilities for conducting public business and provide services, among other uses. Federally-owned lands are generally not managed to produce economic profits. These lands must provide services to the public under multiple use conditions, and they must be managed so as to maintain and enhance environmental quality. This direct responsibility for pursuing ecological integrity is assigned to the federal government in a vast body of legislation that influences the management methods used. Attitudes of landowners also affect management. Long-term views of maintenance of, and investment in, the renewable resources of the land as compared to short-term views of a consumptive type use of these resources may provide vastly different management goals and procedures. These differences in long-term and short-term attitudes in land ownership may also be reflected in the interactions between the private and the public sectors on the land uses proposed and adopted.

It is important to note that the perception people have of their surrounding environment influences their decisions as well, ranging from personal to political attitudes. For example, since a large internal movement of population from cold, humid areas to warmer, drier areas is occurring in the U.S., these settlers' lack of knowledge of arid area constraints may become consequential in decision-making regarding the management of certain drylands resources. People from mesic systems are not prepared to live with the variations of arid climates. "They are often fooled by the system. After a year or two of heavy rains they think they can grow rice. After a mild winter they think they can grow bananas. After a few dry years they will build a house in a dry creek bed. Even after they have been burned, they repeat the foolishness. People have short memories, especially western society people." (Innis, 1978)

The effect on the stewardship of the drylands of this "new" population, specially in the Southwest, has not yet been characterized or assessed.

Table V-1

Cropland Used for Crops; Crop Failure

(millions of acres)

		Cropland Used for Crops	Crop Failure
Great Plains	1939	128.0	13.9
	1956	131.7	14.3
	1977	130.4	4.5
Mountain	1939	25.8	2.7
	1956	35.7	3.0
	1977	36.0	1.1
Pacific	1939	17.8	0.5
	1956	20.8	0.4
	1977	20.7	0.2

Note: 1939 and 1956 were the heights of the 1930's and 1950's Dust Bowls.

Source: Donald D. Duros and Evelyn T. Black, Changes in Farm Production and Efficiency, USDA, November 1978.

Table V-2

Total Acreage Irrigated by Bureau of Reclamation Water Projects - United States

Year	Irrigated Acreage
1920	2,205,420
1971	8,833,998

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Table V-3

Livestock on U.S. National Forest System Lands

	Thousands Grazed		Receipts from Grazing
	Cattle and Horses	Sheep	(000's)
1963	1,339	2,280	$ 4,028
1977	1,542	1,467	$11,443

Note: Most National Forest System Lands grazing occurs in the Western U.S.

Source: USDA, Agricultural Statistics, 1978.

Livestock on Lands Administered by the Bureau of Indian Affairs

Number of Operators	18,688
Number of Cattle	539,300
Number of Horses	51,094
Number of Sheep and Goats	621,817
Animal Unit Months (AUMs) of Use	7,490,430

Source: Private Communication, BIA, June 1980.

Table V-4

Authorized Use of Grazing District Lands, 1975

10 Western States*

	Cattle	Horses	Sheep and Goats
Number of Operators	11,778	130	1,828
Number of Livestock	2,317,353	14,567	2,948,856
Animal Units	2,317,353	14,567	595,767
Animal-Unit-Months of Use	8,608,409	77,629	1,553,151

*AR, CA, CO, ID, MT, NV, NM, OR, UT, WY

Source: Bureau of Land Management, Public Land Statistics, 1976

Table V-4b : Authorized Use of Grazing District Lands

1974 - 1978*

State	1974	1976	1978
	Animal Units		
Arizona	73,312	82,102	90,271
California	74,925	77,266	59,812
Colorado	321,881	336,903	184,488
Idaho	411,319	434,958	356,164
Montana	361,920	338,421	187,166
Nevada	435,682	414,549	353,760
New Mexico	244,848	279,194	188,425
Oregon	203,188	200,795	189,299
Utah	249,486	272,439	198,254
Wyoming	484,392	497,020	289,485
Total	2,860,953	2,933,647	2,097,124

*Grazing year: March 1 of year given to February 28 of the next.

Table V-4c: Authorized Use of Grazing District Lands

1974 - 1978*

State	Animal Unit Months 1974	 1976	 1978
Arizona	515,426	493,240	516,304
California	188,587	250,509	234,488
Colorado	579,430	574,779	441,288
Idaho	1,186,478	1,140,963	1,105,124
Montana	1,247,568	1,078,357	927,999
Nevada	2,039,444	2,019,365	1,846,936
New Mexico	1,462,373	1,480,503	1,412,041
Oregon	922,085	909,468	886,820
Utah	976,795	1,023,088	831,024
Wyoming	1,274,893	1,257,458	1,182,954
Total	10,393,079	10,227,730	9,384,978

*Grazing year: March 1 of the year given to February 28 of the next.

Table V-5

1978 Cattle and Sheep Production

(million head)

Location	Land Ownership	Cattle	Sheep
United States	All	116.3	12.4
17 Western States	All	59.1	9.6
17 Western States	BLM Lands	1.73	1.8

Sources: U.S. Department of Commerce, Statistical Abstract, 1978; BLM/USDI, 1980, private communication.

Table V-6a

Vegetation and Soil Condition

Condition Class	Standards Used
Excellent	76 - 100% of Potential
High	51 - 75%
Medium	26 - 50%
Low	0 - 25%

"Potential" means the climax vegetation and soil condition in a pristine state.

Source: U.S. Dept. of Agriculture, RPA, 1980.

Table V-6

Percentage Productivity Classification of Grazing Land Ecosystems

United States, 1970

	High Productivity	Moderately High Productivity	Moderately Low Productivity	Low Productivity
Grasslands	4.1	17.4	70.6	7.9
Shrublands	2.5	14.2	35.5	47.7
Non-commercial Forests*	3.5	15.5	53.1	27.8

*Lands used mostly for grazing. Excludes non-commercial forest land in other forest ecosystems.

Source: USDA, RPA, 1975.

Table V-7

Average annual herbage and browse production and area by productivity class of range ecosystem in the contiguous States

Ecosystem	Area	Productivity Class*			
		1	2	3	4
		(All figures X 1000 acres)			
Grassland:					
Mountain grasslands	26,871	0	914	20,826	5,131
Plains grasslands	175,233	0	1,826	80,592	92,815
Prairie	41,185	1,985	9,691	29,509	0
Desert grasslands	24,744	0	0	0	24,744
Annual grasslands	10,153	0	1,987	5,992	174
Shrublands:					
Sagebrush	129,961	0	0	61,889	68,072
Desert shrub	81,171	0	0	2,908	78,263
Southwestern shrubsteppe	43,218	0	0	790	42,614
Shinnery	4,726	8	1,689	385	2,644
Texas savanna	28,429	0	5,502	21,610	1,317
Chaparral-mountain shrub	14,120	0	4,207	6,617	3,296
Pinyon-juniper	47,304	0	0	0	47,304
Desert	7,490	0	0	0	0

*Productivity classes: (1) 5,000 pounds or more per acre per year;
(2) 3,000 to 4,999 pounds;
(3) 1,000 to 2,999 pounds;
(4) Less than 1,000 pounds.

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Table V-8

Rangeland Area in the Western States, by Ecosystem, 1976

(Thousand Acres)

State	Total Rangeland and Other Forest Land	Total Rangeland		Other Forest Land	
		Total Grassland	Total Shrublands	Chapparral-Mountain Shrub	Pinyon-Juniper
Arizona	58,822	10,354	34,813	1,629	12,026
California	53,289	17,074	25,965	7,554	2,696
Colorado	35,228	19,421	8,401	2,999	4,407
Idaho	24,014	1,798	21,801	11	404
Kansas	16,278	16,278	0	0	0
Montana	54,154	49,299	4,034	345	476
Nebraska	24,274	24,272	2	0	0
Nevada	61,547	636	56,252	0	4,659
New Mexico	59,833	25,789	22,937	428	10,679
North Dakota	12,296	12,296	0	0	0
Oklahoma	9,301	8,696	605	0	0
Oregon	24,805	3,862	16,462	64	2,417
South Dakota	23,398	23,392	1	4	1
Texas	91,603	44,350	47,253	0	0
Utah	39,705	2,470	27,321	956	1
Washington	7,895	3,813	4,082	0	0
Wyoming	47,609	23,831	23,066	134	578

Table V-9

U.S. Wildlife Habitat Classification, 1975

(by % of total)

Class of Wildlife	Improving	Static	Declining
Big Game	8.0	59.5	32.5
Small Game	10.2	59.5	30.3
Nongame	10.5	57.2	32.3
Fish	22.7	64.8	12.5

Source: Bureau of Land Management, Range Condition Report, Prepared for the Senate Committee on Appropriations, January 2, 1975.

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Table V-10

Participation in selected outdoor recreation activities by people 12 years and older, 1977 1/

Recreation activity	Percentage participating at least once a year	Percentage participating five or more times yearly
Visits to amusement parks, zoos, aquariums, fairs, etc.	73	39
Picnicking	72	49
Driving for pleasure	69	57
Walking or jogging	68	57
Pool swimming and sunbathing	63	49
Sightseeing	62	36
Attending sports events	61	44
Playing outdoor sports or games	56	43
Fishing	53	36
Nature walks, bird-watching, or wildlife photography	50	36
Bicycling	47	39
Nonpool swimming and sunbathing	46	35
Attending dances, concerts, or plays	41	22
Boating (not including sailing or canoeing)	34	20
Tennis	33	24
Camping in developed areas	30	12
Hiking or backpacking	28	16
Use of off-road vehicles or motorcycles	26	20
Camping in primitive areas	21	9
Sledding	21	12
Hunting	19	14
Canoeing, kayaking, or river-running	16	5
Waterskiing	16	8
Golfing	16	11
Ice skating	16	9
Horseback riding	15	8
Sailing	11	5
Snowmobiling	8	5
Downhill skiing	7	4
Cross-country skiing or ski touring	2	1

1/ According to the U.S. Census Bureau, the U.S. population 12 years and older was 174.4 million as of July 1, 1976.

Source: U.S. Department of the Interior, Heritage Conservation and Recreation Service, 1977 National Outdoor Recreation Survey. (USDI, 1978)

Table V-11

Indices of the projected demand to 2030 for outdoor recreation in the conterminous states shown by activity group and type of activity. The base year is 1977 (1977=100).

Activity group and type of activity	Year					
	1977	1990	2000	2010	2020	2030
	(Percentages of 1977 demand)					
Land:						
Camping (developed)-------	100	126	150	181	214	245
Camping (dispersed)-------	100	116	133	157	182	205
Driving off-road vehicles-	100	108	118	129	139	148
Hiking-------------------	100	109	117	132	146	159
Horseback riding---------	100	109	118	139	159	181
Hunting (big game)--------	100	114	125	134	142	148
Hunting (small game)------	100	106	113	118	121	124
Hunting (waterfowl)-------	100	119	133	148	160	169
Nature study--------------	100	110	121	133	145	155
Picnicking----------------	100	112	124	137	150	162
Pleasure driving----------	100	108	116	126	135	143
Sightseeing---------------	100	112	123	136	150	163
Water:						
Canoeing-----------------	100	121	141	175	209	249
Fishing (freshwater)------	100	118	139	157	174	190
Fishing (saltwater)-------	100	130	162	193	225	256
Sailing------------------	100	145	185	239	298	367
Other boating------------	100	119	137	163	189	220
Swimming (outdoor)--------	100	115	127	147	168	190
Waterskiing---------------	100	109	118	140	161	185

(continued on next page)

Table V-11 cont'd.

Indices of the projected demand to 2030 for outdoor recreation in the conterminous states shown by activity group and type of activity. The base year is 1977 (1977=100)

Activity group and type of activity	Year					
	1977	1990	2000	2010	2020	2030
	(Percentages of 1977 demand)					
Snow and ice:						
Cross-country skiing	100	133	161	200	241	280
Downhill skiing	100	142	179	232	289	352
Ice skating	100	123	144	177	212	250
Sledding	100	118	133	163	193	227
Snowmobiling	100	109	120	141	161	181

Sources: U.S. Department of Agriculture, Forest Service. An Assessment of the Forest and Range Land Situation in the United States (in process). Dyer, A.A., and W. E. Wegert. 1978. Demand Analysis and Projections of Use for Hunting and Fishing Opportunities. M.S. Dissertation. College of Forestry and Natural Resources, Colorado State Univ., Fort Collins.

Table V-12

Streamflow Compared with Current Withdrawals and Consumption

(Billion gallons per day)

Region	Mean Annual Run-Off	50% of the Years	90% of the Years	95% of the Years	Fresh Water Consumptive Use, 1970*	Withdrawals 1975*
Missouri	54.1	53.7	29.9	23.9	15.5	38.0
Arkansas-White-Red	95.8	93.4	44.3	33.4	8.0	12.9
Texas-Gulf	39.1	37.5	15.8	11.4	11.3	16.9
Rio Grande	4.9	4.9	2.6	2.1	4.2	6.3
Upper Colorado	13.45	13.45	8.82	7.50	4.4	6.9
Lower Colorado	3.19	2.51	1.07	0.85	4.6	8.9
Great Basin	5.89	5.82	3.12	2.46	3.8	8.0
Columbia-N. Pacific	210.	210.	154.	138.	11.9	37.5
California	65.1	14.1	33.8	25.6	26.6	39.6

Source: Water Resources Council, The Nation's Water Resources, 1968, except *1978.

Y.36

Table V-13

Land Ownership by State

	Arizona	California	Colorado	Idaho	Kansas	Montana
Federal	51,060,000	44,047,518	23,649,157	33,334,522	754,410	37,987,409
State	8,857,000	3,255,515	3,086,164	2,594,837	111,766	5,321,309
Private	12,771,100	52,500,246	42,816,588	16,849,806	51,644,824	50,859,609
Other		1,760,510	293,439	119,081		

	Nebraska	Nevada	New Mexico	No. Dakota	Oklahoma	Oregon
Federal	734,237	61,617,277	32,912,078	3,167,773		32,315,826
State	2,447,456	141,491	9,217,070	3,163,552	No Figures Available	1,539,687
Private	45,277,936	8,986,832	35,637,251	38,894,275		27,837,531
Other	489,491					554,287

	So. Dakota	Texas	Utah	Washington	Wyoming
Federal	8,229,150	3,195,599	37,239,000	13,817,628	31,419,803
State	3,435,373	892,493	3,785,296	3,733,319	4,439,940
Private	37,645,557	164,129,508	11,356,354	22,168,694	26,544,097
Other			160,350	2,885,159	

Note: Indian lands held in trust are included in "Federal."
"Other" includes primarily city- and county-owned land.
If no "Other" category is listed, figures are included in "Private."

Source: Private communications from each State government.

Table V-14

Federally Owned Land

Region	Total Land (1000 acres)	Percent Owned by Federal Government
Great Plains	407,184	3.0
Mountain	548,448	49.1
Pacific	204,500	44.5

Source: U.S. General Services Administration, Inventory Report on Real Property Owned by the United States Throughout the World, 1977

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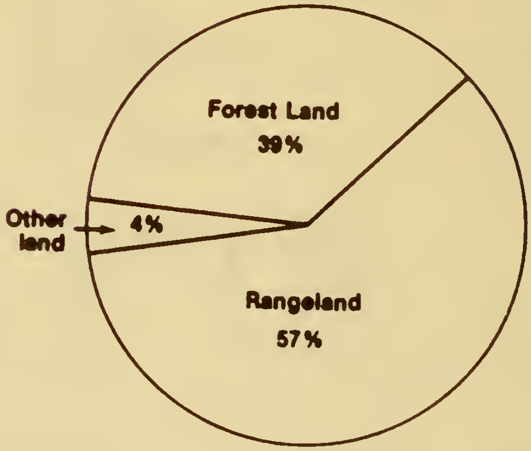
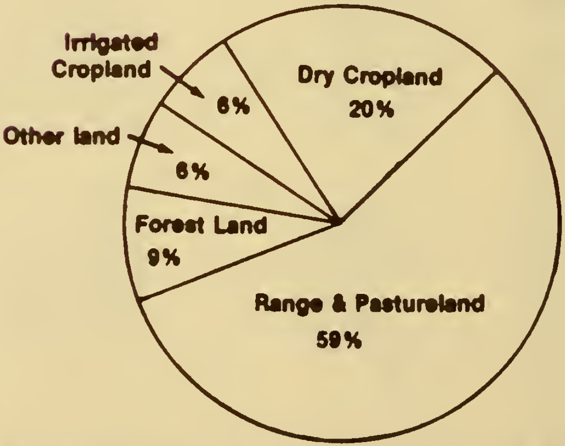
Figure V-1

Land Use in the 17 Western States
Federal Land

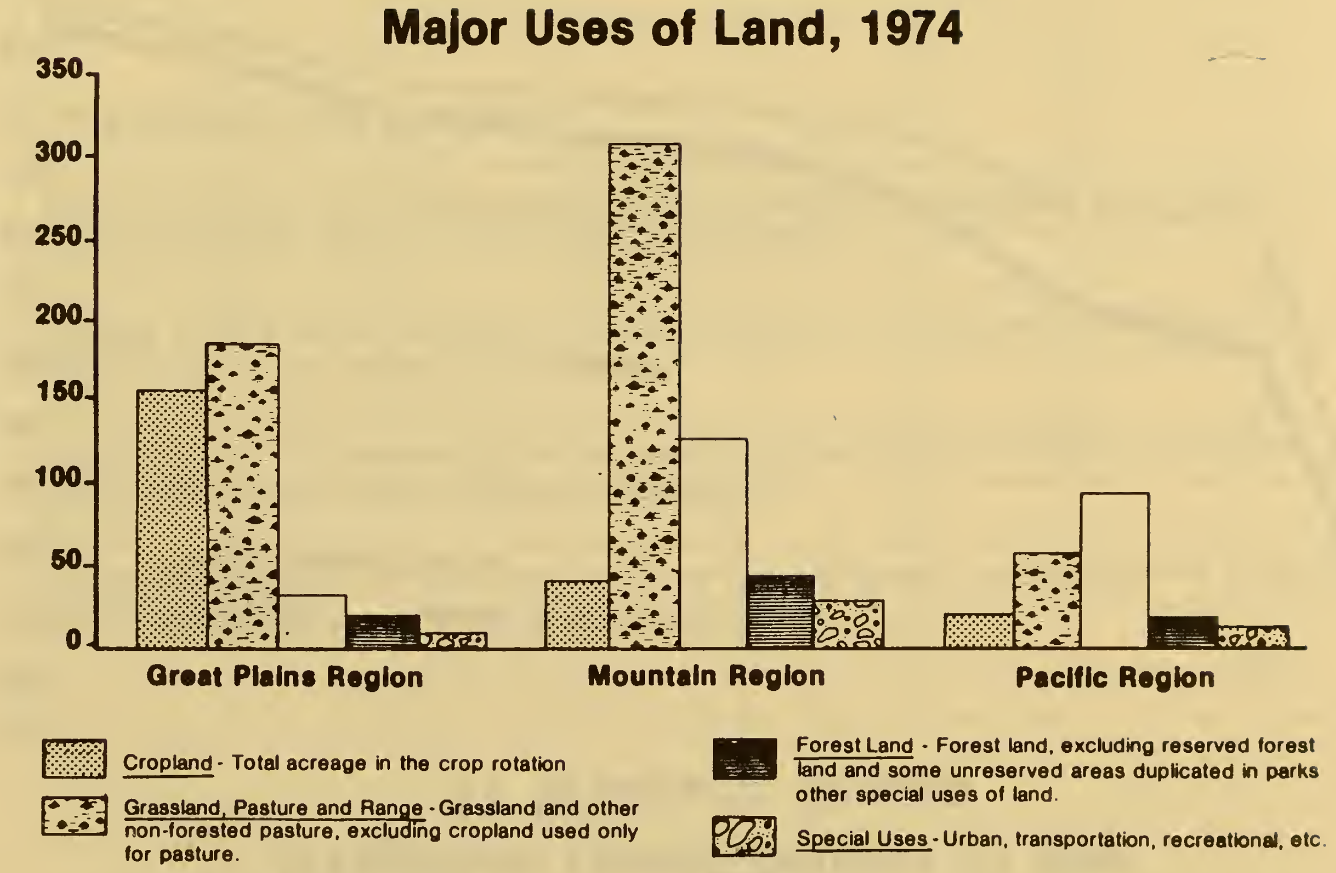


Land Use in the 17 Western States -
Non-Federal Land



Source: Bureau of the Census. Statistical Abstract of the U.S., 1978.

Figure V-2



▨ Cropland - Total acreage in the crop rotation

▨ Grassland, Pasture and Range - Grassland and other non-forested pasture, excluding cropland used only for pasture.

☐ Other Land - Miscellaneous areas with low agricultural use, value, such as marshes, open swamps, bare rock areas, deserts, and tundra.

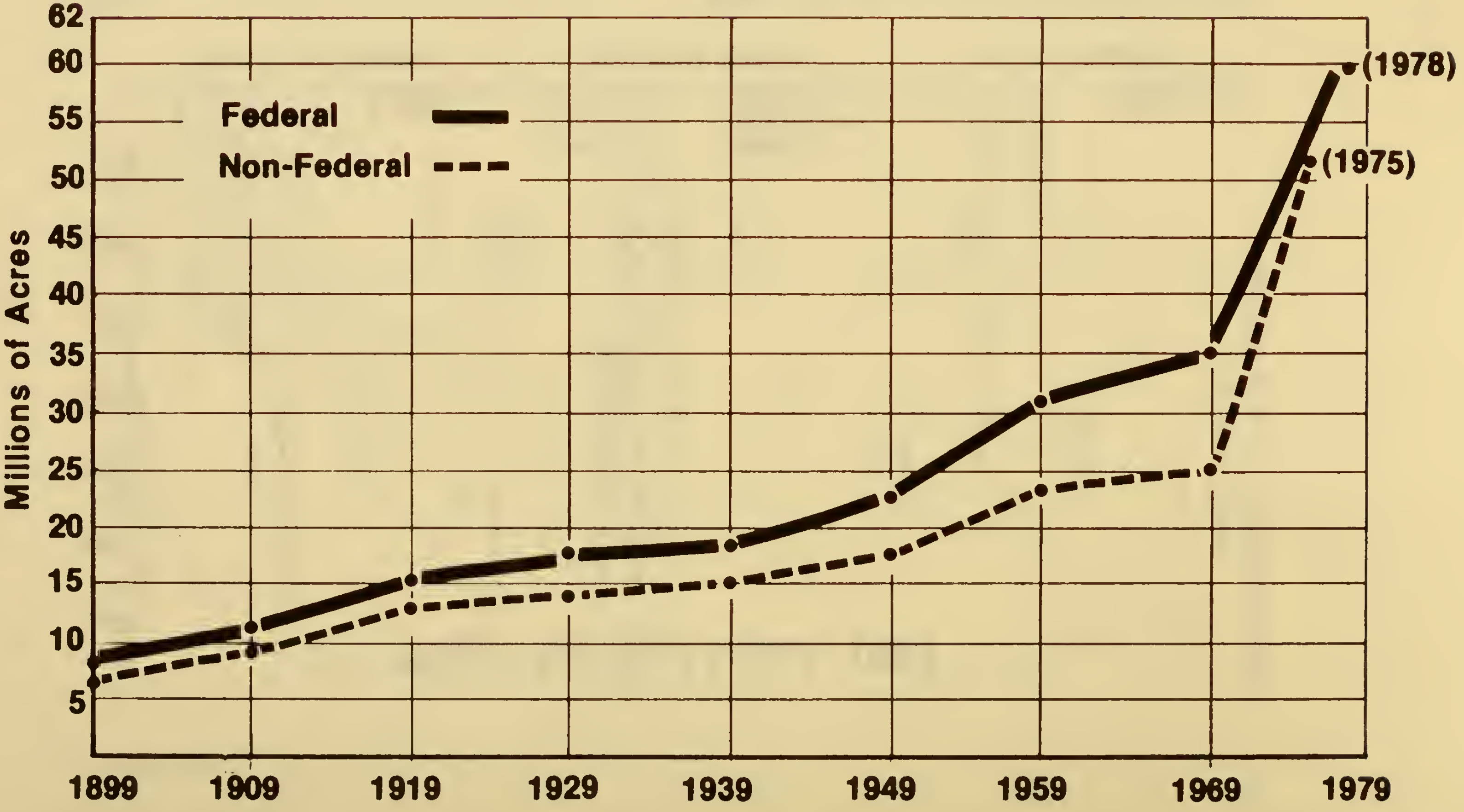
■ Forest Land - Forest land, excluding reserved forest land and some unreserved areas duplicated in parks other special uses of land.

▨ Special Uses - Urban, transportation, recreational, etc.

Source: H. Thomas Frey, Major Uses of Land in the United States, 1974. Washington: USDA, November 1979.

Figure V-3

Irrigation Development in the 17 Western States



Source: National Water Commission, Water Policies for the Future, 1973
& BuRec, Water & Land Resource Accomplishments, 1978

Figure V-4a

Rangeland Conditions

The problem was rated as—

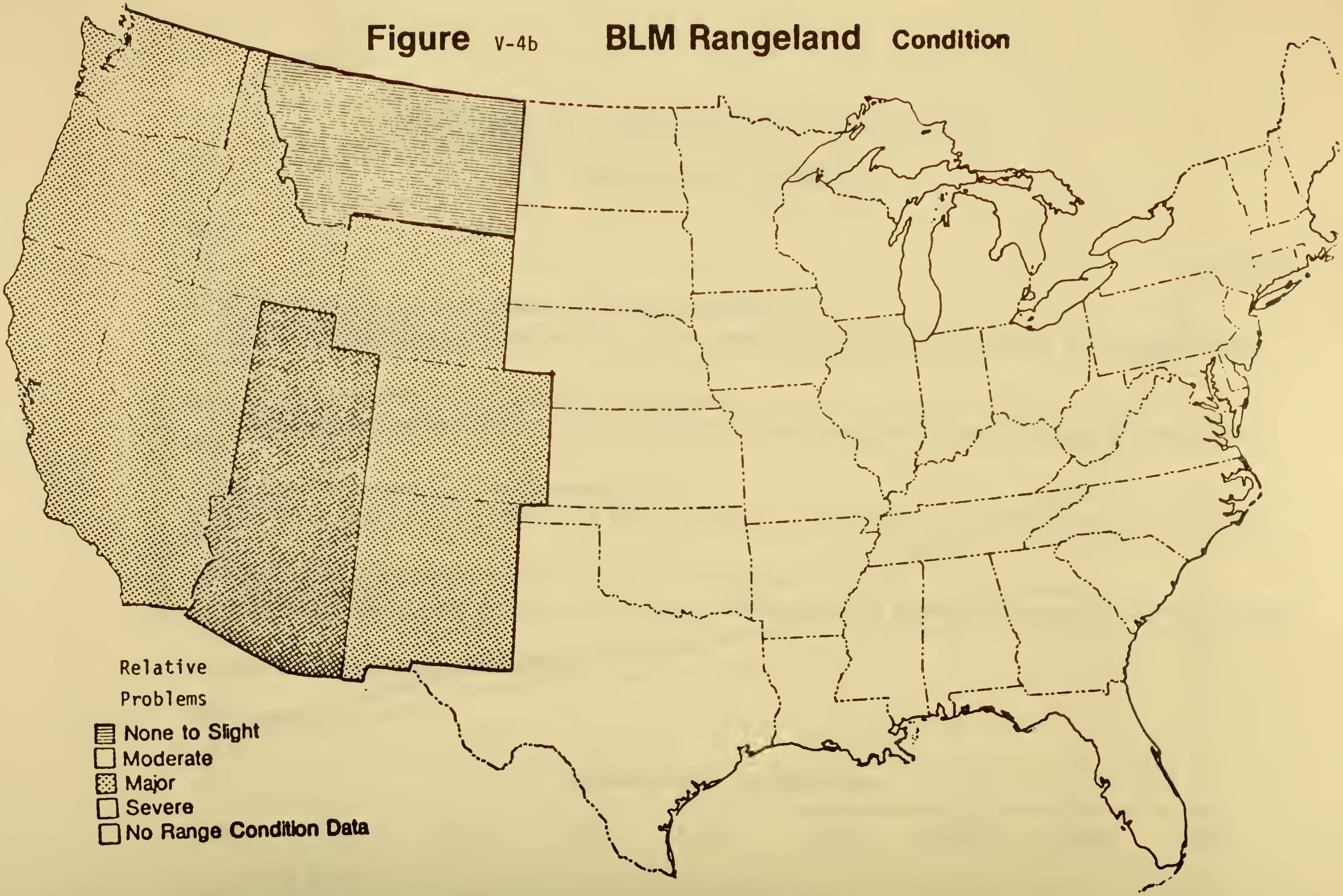
Severe if less than 20 percent of the range was in good or excellent condition or more than 40 percent was in poor condition.

Major if less than 40 percent was in good or excellent condition and more than 20 percent was in poor condition.

Moderate if 20 percent or more was in good and excellent condition and less than 20 percent was in poor condition.

None to slight if 40 percent or more was in good and excellent condition and less than 20 percent was in poor condition.

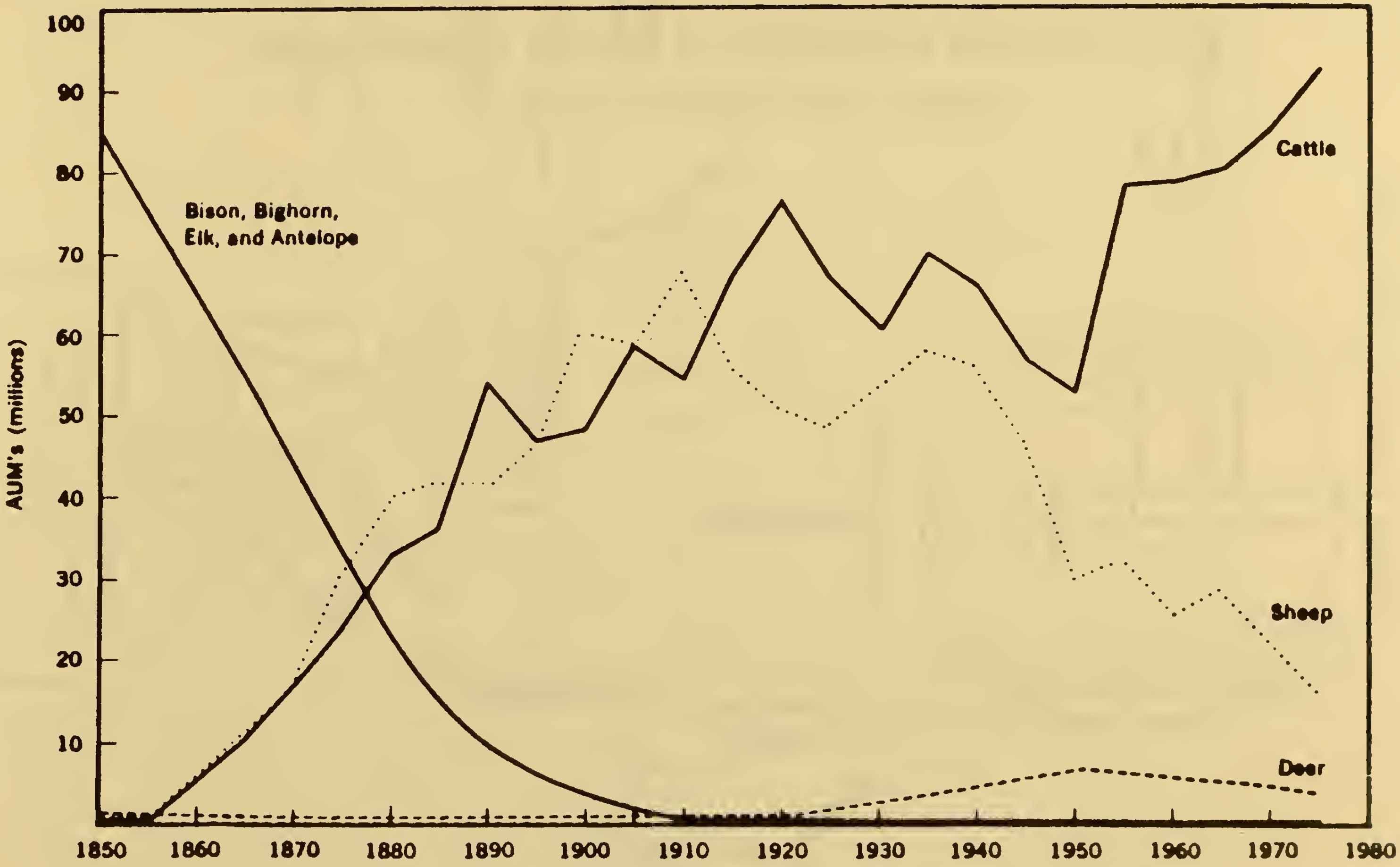
Figure V-4b **BLM Rangeland** **Condition**



V-4/b

7 -

Figure V-4c

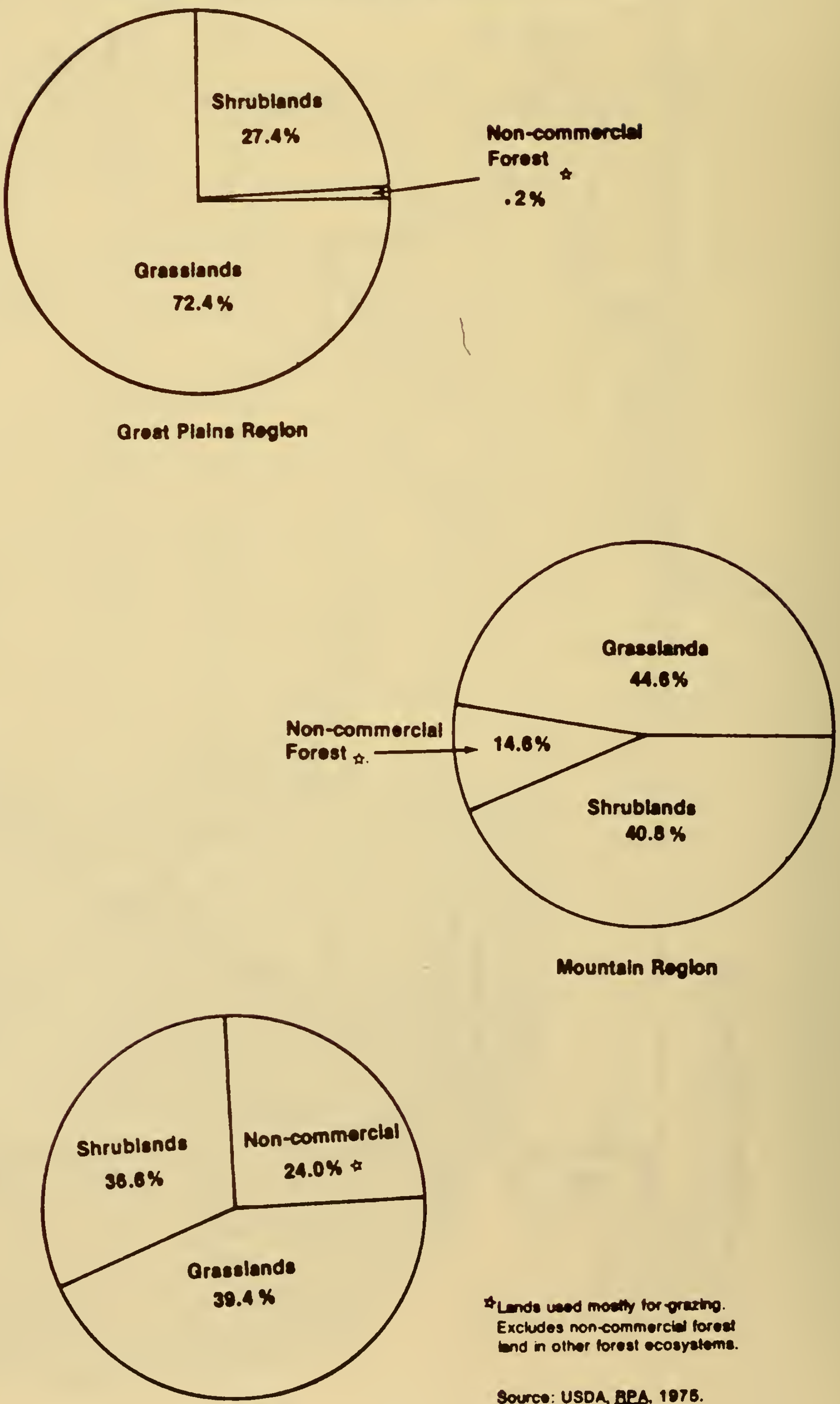


Conjectured AUM's of wild and domestic grazing pressures on rangelands of the 11 western states.

V.42

Figure V-5

Grazing Land Ecosystems - 1970



Great Plains Region

Mountain Region

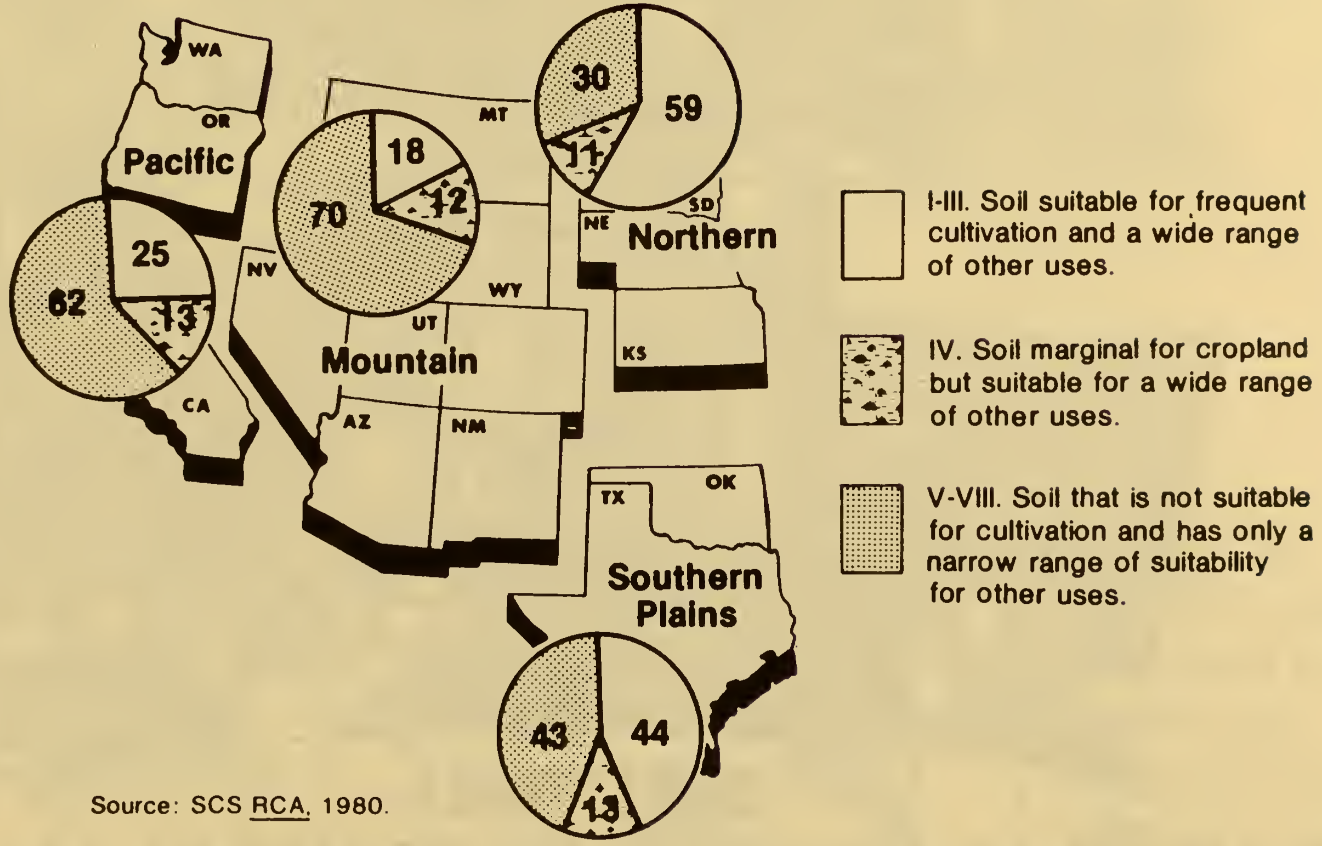
Pacific

☆Lands used mostly for grazing. Excludes non-commercial forest land in other forest ecosystems.

Source: USDA, RPA, 1975.

Figure V-6

Percentages of soil in capability classes I-VIII, by farm production region.


WA
OR
Pacific
25
13
62
CA
NV
MT
18
12
70
WY
UT
Mountain
AZ
NM
30
59
11
SD
NE
Northern
KS
TX
OK
Southern Plains
44
13
43
I-III. Soil suitable for frequent cultivation and a wide range of other uses.
IV. Soil marginal for cropland but suitable for a wide range of other uses.
V-VIII. Soil that is not suitable for cultivation and has only a narrow range of suitability for other uses.

Source: SCS RCA, 1980.

PERCENT CHANGE IN TOTAL POPULATION
1960-1970

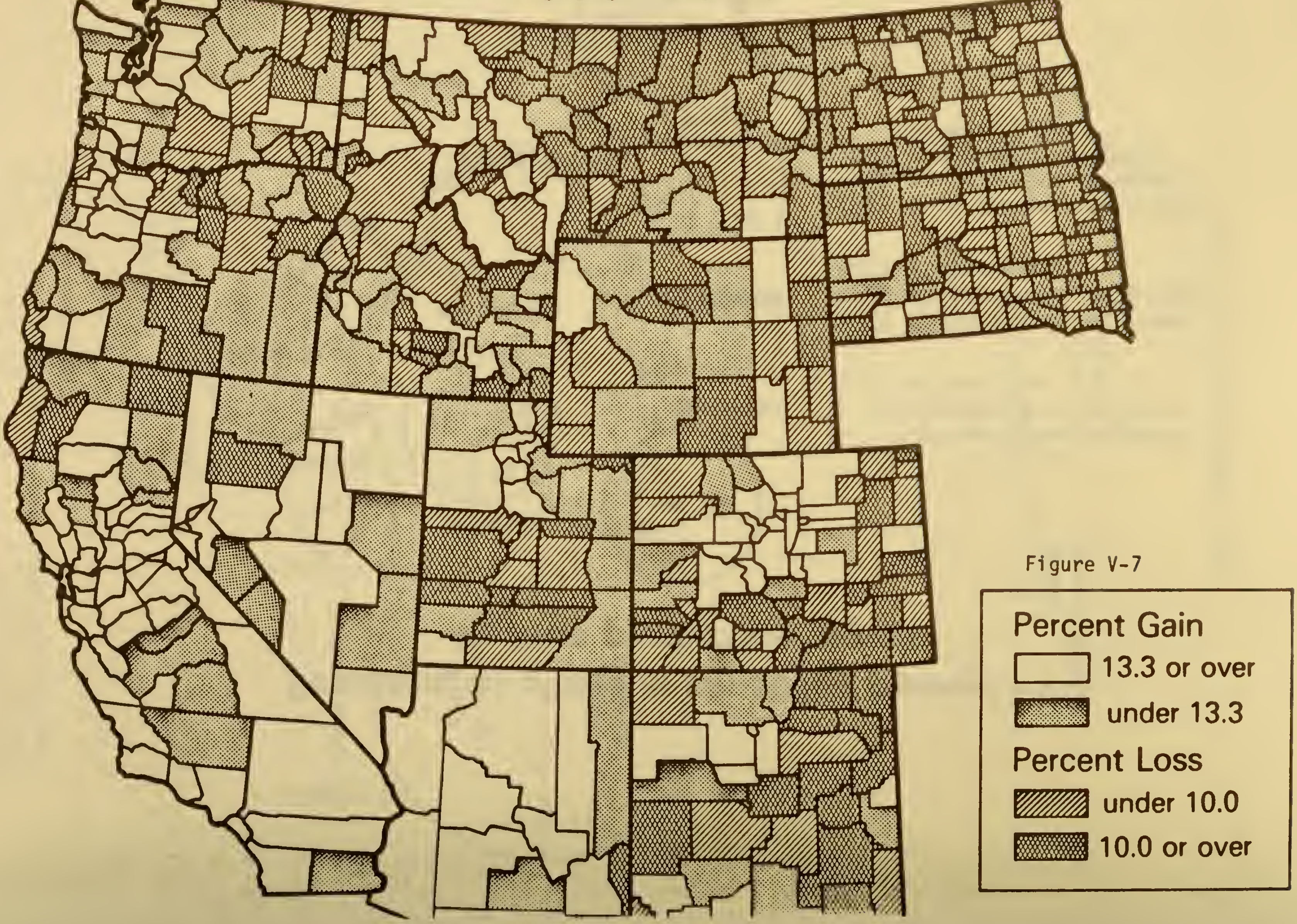


Figure V-7

V.45

PERCENT CHANGE IN TOTAL POPULATION
1970–1975

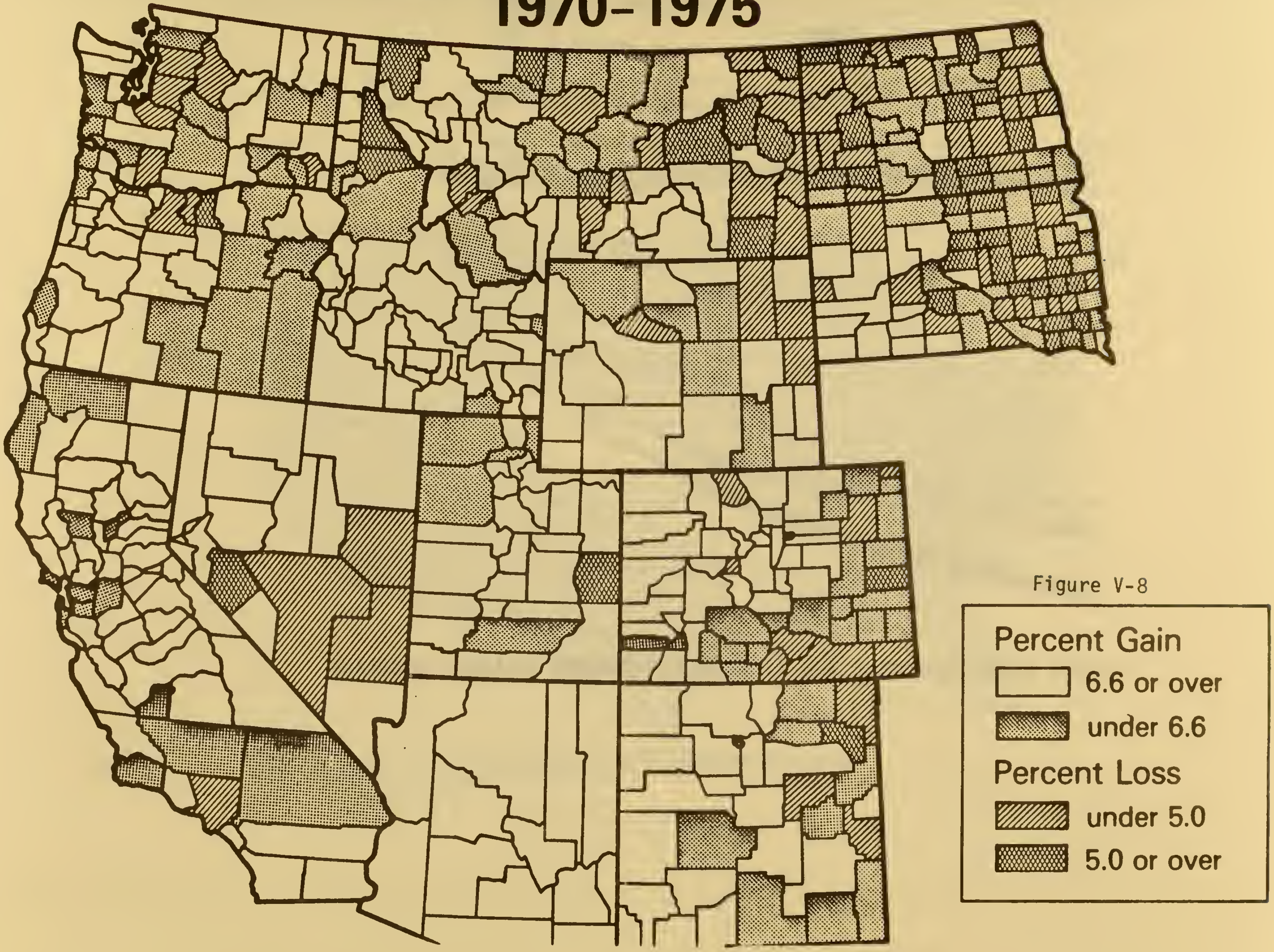
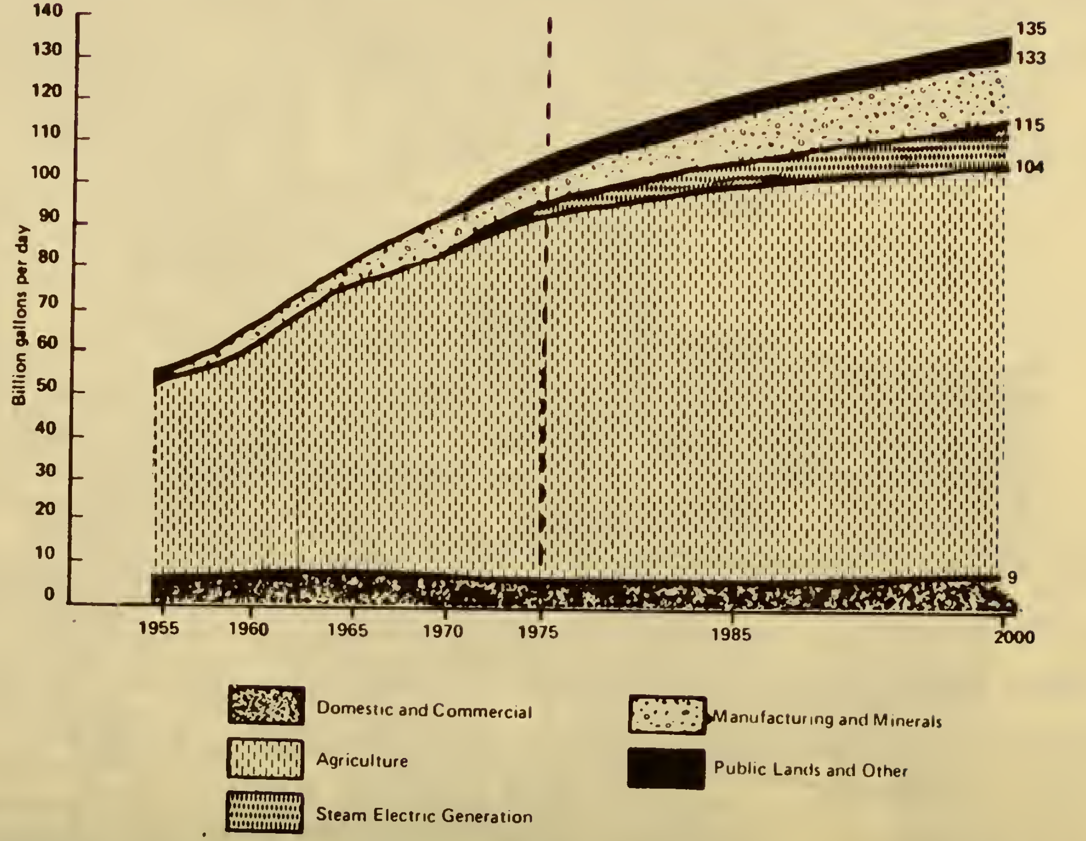


Figure V-8

V.46

Figure V-9

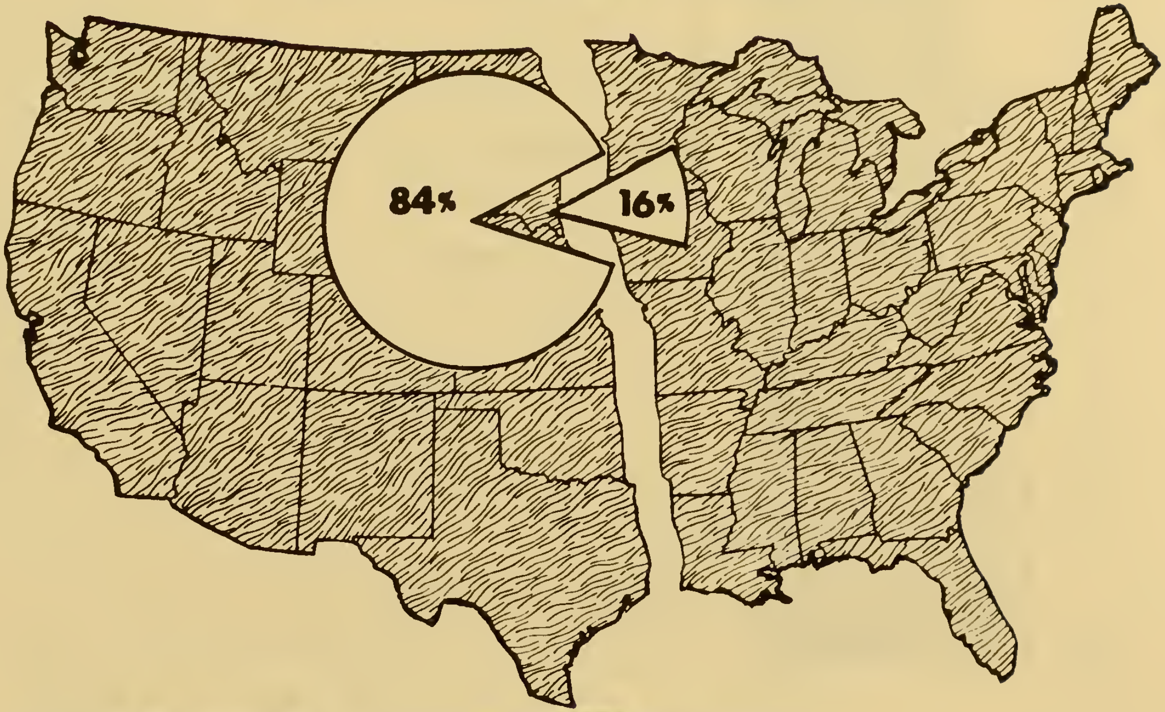
Fresh-water Consumption by Functional Use



Source: WRC. The Nation's Water Resources, 1975-2000.

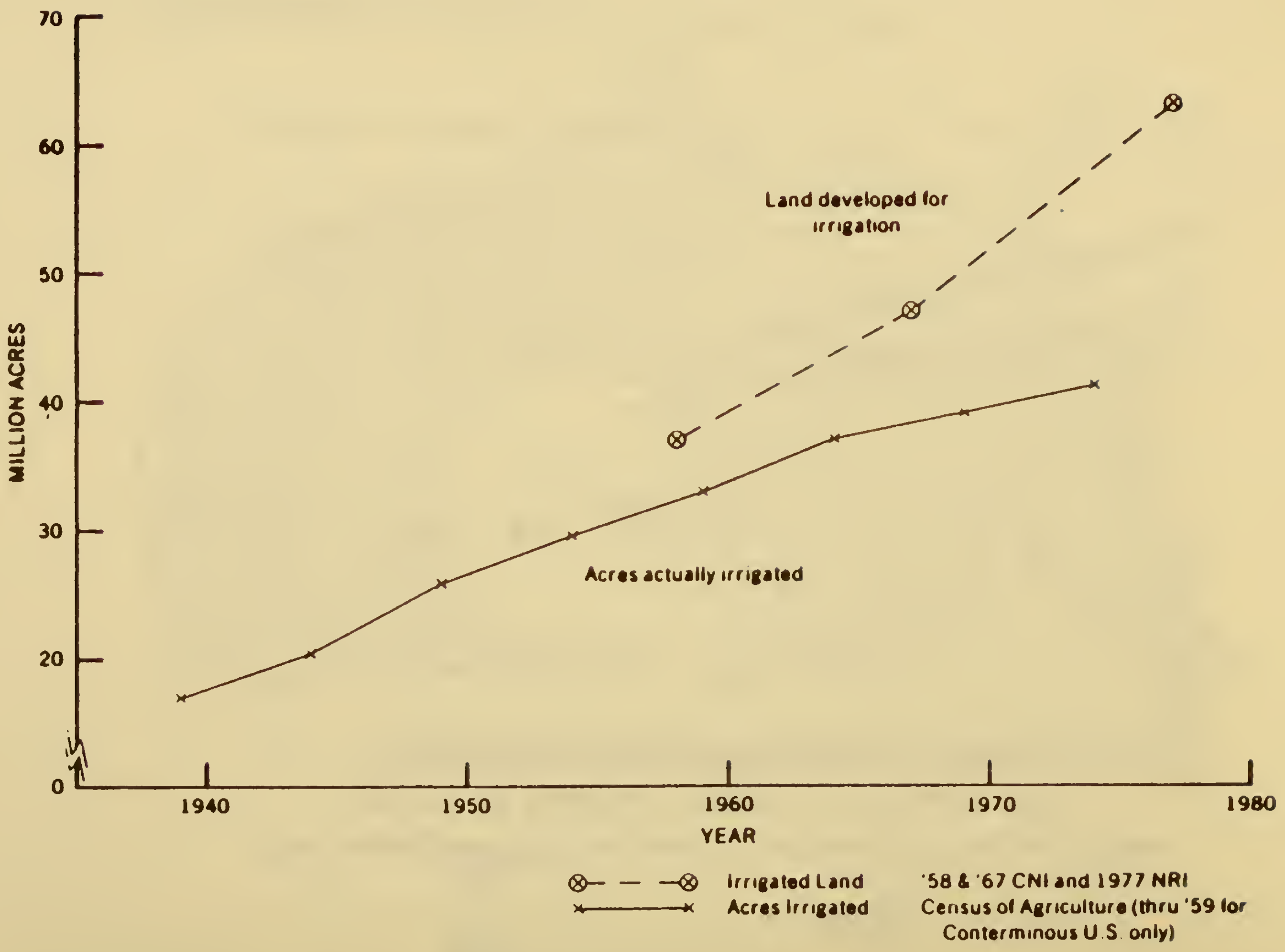
Figure V-10

Percentage of Off-stream Freshwater Consumption in the 17 Western States Compared with that in the 31 Eastern States, 1975.



Source. C. Richard Murray and E. Bodette Reeves, *Estimated Use of Water in the United States in 1975*, USGS, 1977.

Figure V-11

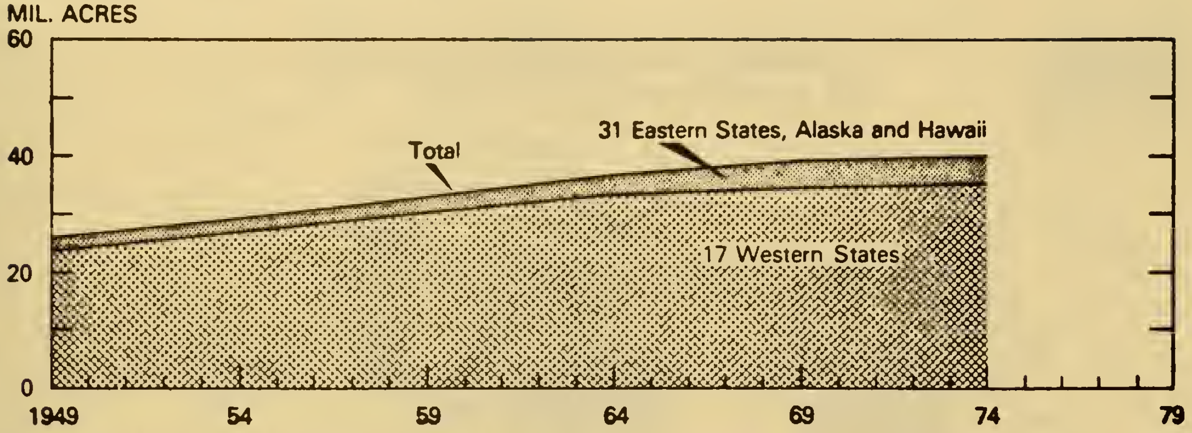


Irrigated land, 1939-1977.

Source: USDA, RCA, 1980.

Figure V-12

IRRIGATED LAND IN FARMS

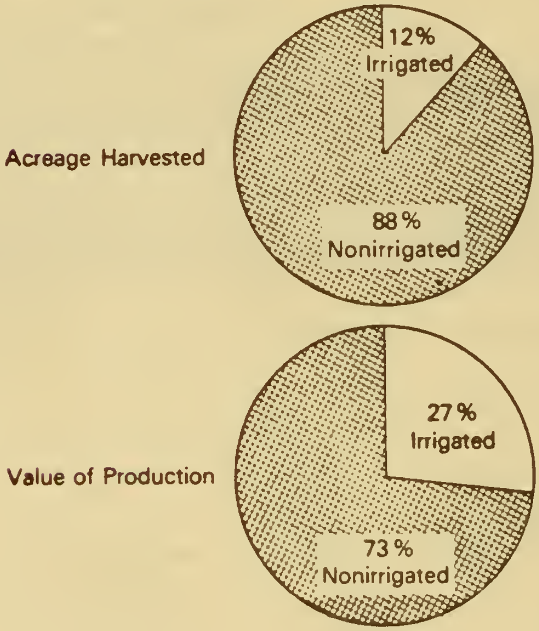


Data plotted on a 5-year basis, corresponding with the U.S. Census of Agriculture.

Source: USDA, 1978 Handbook of Agricultural Charts.

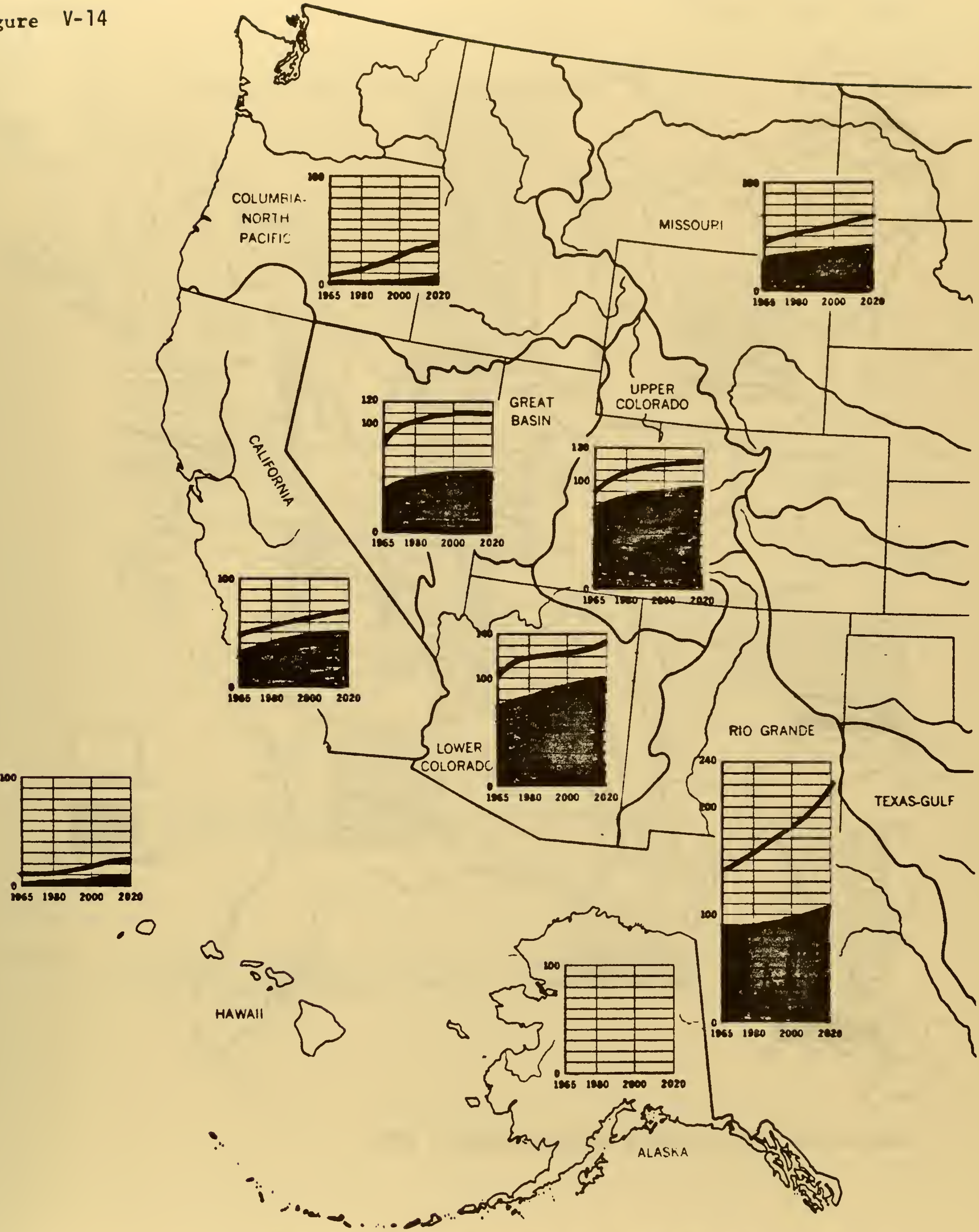
Figure V-13

IRRIGATED AND NONIRRIGATED ACREAGE HARVESTED AND VALUE OF PRODUCTION



Source: USDA, 1978 Handbook of Agricultural Charts.

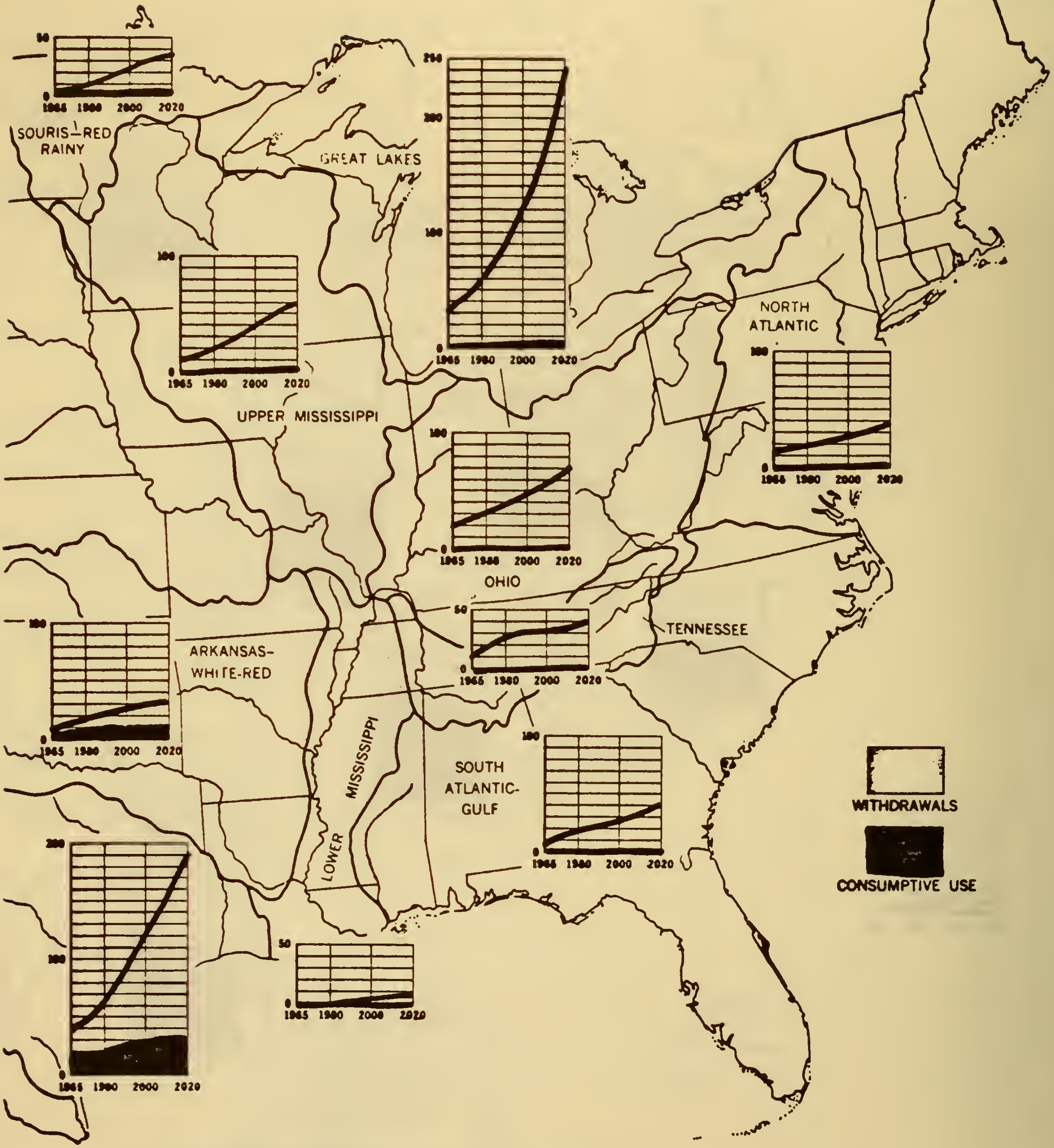
Figure V-14



Regional indices of projected water withdrawals and consumptive uses, 1965–2020 (estimated average supply equals 100).

V.52

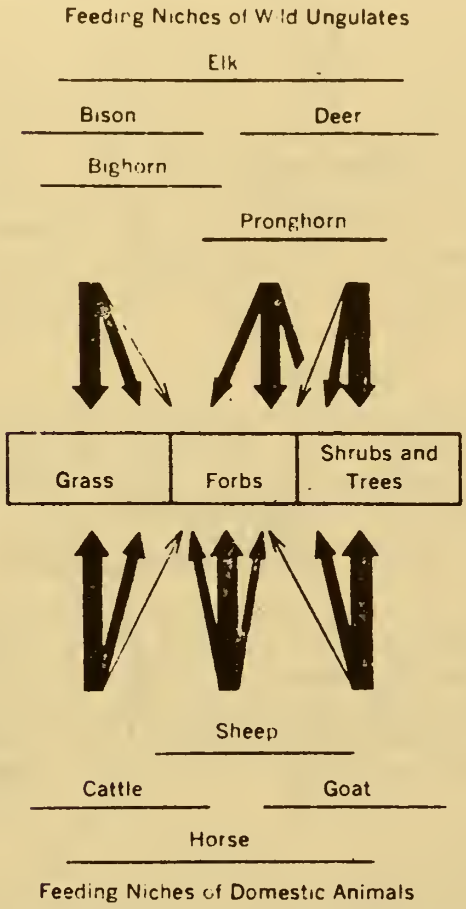
Figure V-14 con't.



Source: WRC, The Nation's Water Resources, 1968.

Figure V-15

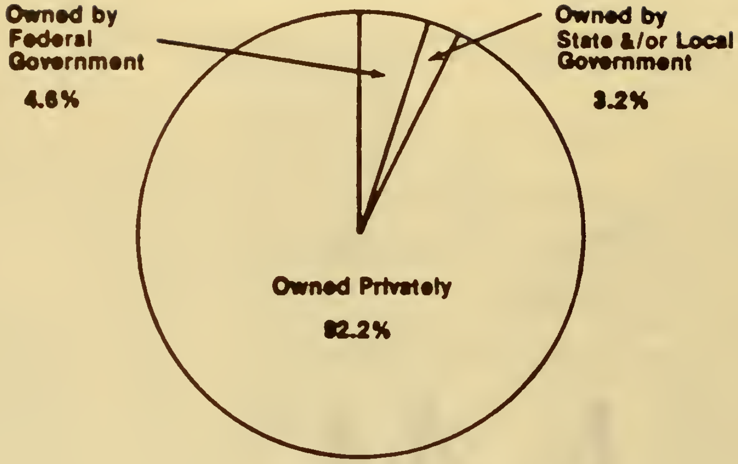
Feeding niches of wild ungulates and domestic herbivores and potential competition between them



[1] Strength of the arrows symbolizes approximate feeding preferences. Potential for competition is greatest when two species have similar preferences.

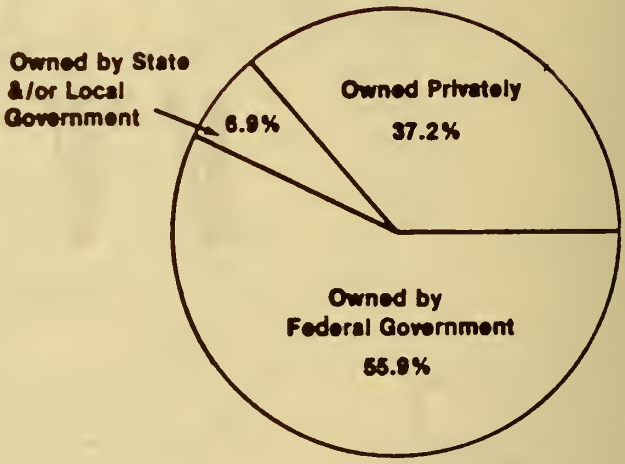
Source: Frederic H. Wagner, "Livestock Grazing and the Livestock Industry," in Wildlife and America, Howard P. Brokaw, ed., CEQ, 1978.

Land Ownership, 1979

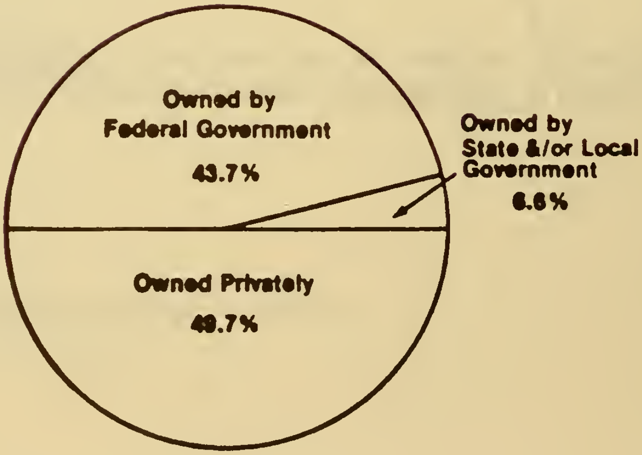


Great Plains

Figure V-16



Mountain



Pacific

Source: Private communications from each State, 1979.

Y. 55

VI. Indicators of Desertification

The complex processes affecting desertification, previously discussed in Sections IV and V can be understood and subjected to inventory and monitoring procedures described in Section VII when based on an agreed-upon interdisciplinary set of critical indicators. This need was recognized in the course of studies which accompanied the UN Conference of 1977. Two resulting studies, an analysis of critical indicators prepared by Clark University for the U.S. Agency for International Development, and a Handbook on Desertification Indicators compiled by the American Association for the Advancement of Science for a seminar held in 1977, provide the basic material for this chapter on indicators.

The set of integrated indicators of desertification is based on physical, social, and biological factors. Each of the selected indicators should provide a diagnostic index of some component of the process. The list is in a state of constant revision and refinement as additional knowledge of the desertification processes is acquired.

Some principles for indicators are that: (1) they should be directly measurable; (2) the unit of geographic reference must be specified (whether one meter or transcontinental); (3) the stage of desertification should be specified, recognizing that phases of desertification range from mild effects to practically irreversible conditions; and (4) numerical and qualitative standards must be associated wherever possible.

The importance of an agreed-upon set of indicators is based on the need to avoid overaccumulation and underanalysis of data both because of cost considerations and the adverse effects of overloading analysts and decisionmakers. It is also necessary to provide sets of indicators reflecting regional differences both in physical parameters and in social institutions. To facilitate practical monitoring programs it is useful to establish representative sample areas to serve as readily-observed benchmarks or "control" sites.

As discussed in the section on monitoring systems (Section VII) which follows, the United States has long established and comprehensive systems for gathering data on the physical, biological, and social contributors to desertified land. Improvements in capability through advanced remote sensing collection and computerized data processing are underway. Nevertheless, even with a substantial data base, numerous sources have pointed out that current systems are not presently organized satisfactorily for systematic documentation of the progress of desertification. For example, while there is much crop production data in the United States, there is relatively little measurement of productivity in terms of the balance between declining natural productivity and increasing inputs of fertilizer and energy.

Three sets of linked, critical indicators were defined by the Nairobi Seminar on Desertification. They are presented here in the accompanying tables, in simplified form under the broad headings: (1) physical; (2) biological/agricultural; and (3) social. In addition to indicator classes, tables 1 and 2 also show sources of observations or data, for example, ground or remote sensing, desired frequency of observation and background data variables.

This list of indicators has been modified in this study for adaptation to the situation currently prevailing in the United States. Thus, physical factors include climate, soil and water; biological factors include flora and fauna; and social indicators address population dynamics, economic dynamics, and production or economic uses of the land. A brief discussion amplifying each of these categories follows.

Climate

The characteristics of climate in the arid and semiarid West are discussed elsewhere in this study. Persistence of periods of low rainfall is a characteristic meteorological feature. Coordination of rainfall information with other information on change such as measures of bare ground and dust storms are provided through a number of services. On a global basis, the World Weather Watch (WWW) gathers climatic data from synoptic stations which includes cloud cover, vertical temperature, humidity, snow cover, land surface temperature, precipitation and so on. Major abnormal weather conditions are reported weekly by the National Oceanic and Atmospheric Administration (NOAA). Solar radiation, ozone, carbon dioxide and sulphur dioxide, all contributors to climate and climate change, are also monitored and reported by NOAA. While the reports have no direct link to desertification processes, the data is designed to help land managers deal with declining productivity. The present objective of climatologists is to provide long-term "benchmark" data in order to detect climatic shifts, using trends derived from studies of archeology, paleontology, dendrochronology (tree rings), etc., for determining past climates.

Soil

The washing away or blowing away of soil is an important indicator of desertification which is regularly measured both in situ and in transport. Hydrological data on suspended sediments have been recorded for parts of the Southwest U.S. for many decades. Some of the quality-of-soil indicators, also listed in table 1, are depth, organic content, crusts and salinity. Degradation of soil may occur

VI.2

in progressive stages requiring different sets of indicators to monitor. An increase in toxic elements, such as salts or alkalis, affects vegetation, microorganisms and pH, will be unfavorable to growth, and decreases permeability, and amount of usable water. In advanced stages the visible manifestations are likely to be white or gray surface coloration and saline crusts. Degradation of soil structure will be evidenced by textural changes and by eventual surface appearance of dunes or gullies, or other features. Deterioration of fertility may also be a result of physical and chemical conditions. Interpretation of complex soil interactions draws on geomorphology and hydrology as well as soil science.

Water

The progressive loss of ground water and ground moisture is a significant indicator of desertification and requires measurement of standing water and drainage systems as well as ground water depth and quality (table 1). Ground water depth is important to the use of wells to tap underground aquifers. On the other hand, a rise may warn of approaching waterlogging. Drainage refers to the magnitude and continuity of water flows in a drainage basin, including the sediment load. Irregular flow of water may be due to such factors as desertification in upstream areas, poor distribution or reduced soil absorption. Finally, even where the annual total rainfall is low, rainfall may occur in heavy downpours, increasing the likelihood of high runoff and water erosion.

Flora

The biological/agricultural indicators include cover, above-ground biomass, yield, and the distribution and frequency of key species (table VI-2). The single most important biological indicator is change in perennial plant cover or production. However, it must be noted that the quality of plant cover must be recorded since brushes and weeds may be present. Above-ground biomass consists of grasses, forbs, trees and shrubs. Change in plant density and increase in the relative number of weed species, xerophytic species, and of unpalatable plant species are indicative of a downward trend. Vigor of species, grasses for example, is important to observe. Prediction of trends depends upon appropriate sampling, taking into account size, production, and density of desired subject vegetation and the characteristics of particular mixed stands.

W1.3

Fauna

Fauna indicators include key species of wildlife as well as domestic animal populations. Insects, birds, vertebrates, and some species of small animals, particularly rodents, can be identified as key indicators of desertification. Population of domestic animals encompasses numbers and types of stock. Of special importance is the proportion of the number of animals to units of grazing land. This range carrying capacity is normally considered to be site-specific. The concept of carrying capacity in renewable resource management is used to indicate the level of sustained use at which the resource will not be permanently damaged or its productive capacity lowered. There is a close correlation between flora and fauna indicators, especially when applied to rangeland condition. Since a high proportion of cattle are living in arid or semiarid areas, the rangeland indicators become of particular importance. One of the better indicators of trend, in addition to condition of the soils, is the presence and production of plants in relation to the production by species in the climax community on the same ecological site. In this way, flora actually determines fauna.

Social Indicators

The factors dealt with above, concerning physical and biological indicators, interact in a very complex way with "social" variables, that is, the wide range of human activities which impact directly and indirectly on the range of environmental attributes. Table VI-3 has broken the social indicators down by change in land use, settlement pattern, human biological parameters, and social process parameters. As pointed out in The Handbook on Desertification Indicators, "any social indicators selected are more likely to be suggestive of desertification rather than positive proofs of its existence." Social indicators assume a temporal dimension, a means of indicating trends in human land-use activities.

Indicators, or variables, are selected because they show the presence of, or are symptomatic of, environmental stress. The key feature of each is gradual or sudden change. Conditions to be illuminated are population, livelihood, production, and social functions. This report will arbitrarily address the indicators under the following three categories: population dynamics; economic dynamics; and production, that is, economic uses of the land. The actual application and interpretation of indicator data will be performed on a site-specific or local basis. Different indicators may be associated with different areas for spatial reference. A composite index appropriate to one place may not be appropriate elsewhere. Finally, indicators should be chosen so as to be capable of measuring success in combatting desertification as well as degradation.

VI.4

Population Dynamics

Rates of population growth can be documented, with varying degrees of reliability, with national census and economic statistics. Thus, a migration between the rural and urban areas is observed to be occurring in the Western U.S. and from the Snow Belt-eastern U.S. to the Sun Belt-western U.S. The result of these movements is an increase in the urban and suburban population of the 17 Western States. These shifts of populations (seen in figure V-1) are causing social and economic changes in the region.

Many of the social indicators such as changes in land use, changes in settlement pattern, and pressure on water, soils, and vegetation resources, point to demands being placed on resources as an inexorable result of population growth (see figure VI-2). However, the extraordinary range of population densities accommodated within broadly similar climatic zones prevents simple conclusions regarding the carrying capacities of drylands.

Baseline studies of population in areas subject to desertification are possible through census data analysis and can, in some instances, be correlated with trends in well-being, through nutritional and public health data to derive some measure of effects of changing economic conditions. However, human biological indicators are very complex and need to be used with care.

Economic Dynamics

Frequently, indirect human activities can contribute to desertification. Examples of such factors are unexpected side effects of administrative or fiscal change at the national level, rising expectations and economic demand in neighboring areas, or change in market conditions in regional centers. Areas vulnerable to desertification are generally (though not always) relatively sparsely populated and their economies are therefore exposed to the effects of dynamic social and economic events or related areas with denser populations, of investment centers, and of political capitals. When these processes cause changes in the pressure of human use on the renewable natural resources of vulnerable areas, desertification may set in or increase. Local changes caused by these pressures, whether direct or indirect, , may be seen in changes in land use patterns and changes in the distribution of population in relation to effective use of resources, and changes of the economic base (table VI-1

Social changes that may be predictive include changes in the distribution of occupations, income, or property-holding patterns. Changes which may be beneficial may also require increased prudence to protect against negative impacts due to accelerated resource demands. Some change factors may also affect desertification. Reduction in productivity can lead to changes in redistribution patterns, to migration and to increased conflict over resources. The physical and biological indicators discussed above are caused by, and lead to, a number of complex interrelated social processes which in some cases can be measured and thus used as indicators of desertification.

The process of marginalization can be utilized as an indicator. There is a tendency for investments in arid areas to be self-reinforcing factors of lower income and lower population density, creating the predisposing conditions for lower levels of investment. A trend toward more development makes the peoples of the vulnerable areas more dependent on investment from outside.

In the United States, the well-developed census system permits monitoring the cash income of farmers as an economic group. Since it measures the reality of resources available to meet felt needs and financial obligations, a fluctuation in cash income indicates the ability of farmers to hold on to their farms and may suggest the degree of risk and damage to the environment they are willing to accept in order to do so.

Some of the more evident damages and costs of degraded land can be useful as indicators of desertification. It has been estimated, for instance, that more than $15 billion has been spent since the 1930s on soil conservation practices. It must be added that, in fuel costs alone for example, an estimated 2.1 billion gallons of fuel equivalents are used each year (as of 1975) to offset soil erosion in the United States.(figure VI-3 and VI-4; table VI-5).

The Agricultural Conservation Program invested around $87 million (in 1977) in the 17 Western States for soil, water, and timber conservation. The funds appropriated by state and local governments in the Western soil conservation districts were about $43 million in 1977. Rough estimates on the costs of rehabilitating slightly, moderately, and severely desertified land are: $8 per acre for rangeland; $40 per acre for dryland farms; and $250 per acre for irrigated cropland. Areas of severe desertification might cost several times more. One specialist, Dregne, estimates that, in Texas alone, treatment of deteriorated rangeland costs around $500 million, and $900 million for croplands.(figure VI-5).

The difficulty of applying economic factors as an indicator is that the known and unknown costs to be paid when desertification damages occur; the investments to be made to prevent, arrest, and ameliorate desertification; and the benefits resulting from these measures, cannot be readily handled by present analytical methods. In general, calculations and measurements have been made on fragments of the system without considering the interrelationships between the physical, ecological, economic, social, and political parts, and the need to approach the problem in a holistic way.

Of the many questions to be asked with regard to the real price of desertification, these are but a sample:

--In the U.S. drylands, do all the true inputs balance the outputs? Would taking the financial bias out of the sytem make a difference?

--How much does it cost the region and the nation to exploit in the short term the natural resources of the area, in effect reducing their long-term yield?

--What is the impact of the changes in the size of agricultural holdings, brought about by desertification on the local, regional, and national economies?

--What is the impact of shifts in employment in rural communities to new activities?

--What is the value of the "pristine environment" and of unique sites and biomes threatened by runaway development?

--What are the real trade-offs between the development of nonrenewable resources and the quality of renewable resources, when the whole chain of long-term impacts and the energy budgets are considered?

--What are the benefits, if any, between preventive and remedial actions where environmental quality is concerned? An example would be to compare the costs of re-establishing the vegetative cover in parts of the Rio Grande basin against the water treatment costs necessary to remove sediments and salt loads so as to comply with EPA regulations.

--What are the effects of air quality on the health, social, and economic conditions of populations impacted by desertification, and how much does this cost society?

In closing, a point should be made: efficiency, in economic terms, means obtaining the greatest output in relation to inputs. This is desirable but not sufficient, especially in the formulation of policy on resource utilization. A clear understanding of who benefits, who pays, and to what extent each, is necessary to ensure acceptance based on economic equity. The problem is that economic equity or economic welfare is not as easy to compute as economic efficiency. Gains and losses in economic welfare are very difficult to define and measure. Appreciation of who gains, directly

VI.7

or indirectly; how much who shares; who bears the costs; and how gains and costs are related; varies among groups and individuals. Perceived inequities may offend or antagonize people and conservation/management programs, though they may be sound, may or may not be adopted on the basis of such an appreciation. The question remaining involves the "optimum" degree of inequality that the affected population, group or individual, will tolerate or find acceptable. To this question there is no well-defined, simple answer. The best approximation is to describe the existing inequalities in contrast to those that would result from possible courses of action, so as to provide some tolerable choices (Clawson, 1975).

Economic Uses of the Land

Change in type of land use may be related to technology, to land tenure change, or to population growth. Two social factors to monitor are market change in the type of land use, and the introduction of mechanization, in particular deep plowing, which causes the soil to lose its protective cover more readily.

The people best acquainted with problems of desertification are frequently the residents of the affected areas. Through public participation in plans for remedial action it is possible to adjust indicators based on local perceptions of desertification, local priorities for remedial action and existing, locally-based systems for regulating land and water use.

A need, dictated by monitoring limitations, is to devise representative samples at all levels which can provide accurate information about "indicative" areas or "biomes" which can be generalized for larger areas.

By examining various arid land occupancy patterns, a number of specific social, or human activities, indicators may be identified. Thus, the social indicator aspect of irrigation has to do with management--with the delivery of the optimal amount of water at the proper times, and with the allocation of water since water is a scarce commodity in an irrigation system. Similarly, control of salinization is a complex problem and the longevity of mitigating systems, such as artificial drainage, is not yet known. Social factors to monitor in this instance are: separation of water management from land management; changes in type of social organization controlling the irrigation system; reduced maintenance efforts; and an increase in formal and informal disputes over water rights.

Changes and type of dryland agriculture usage is another important indicator. The type of agriculture practices in dryland areas, and especially changes in it, are both important. Much scientific research provides support for the view that conversion of marginal drylands from range use to agricultural use is one of the principal causes of desertification. An obvious consequence of such a change is the destruction or the degradation of perennial cover, especially the amount of dry season cover, and changes in the regeneration rate of vegetation. Another factor to note is the differential production of food calories between range use and cultivation. When there is pressure to increase production, the motivation to convert land from range to agriculture grows very strong.

The uses of rangeland provide indicators since range systems are responsive to both short- and long-term trends in market demand and directed planning. Pushed too far, either system can result in degradational land use changes. The methods used to monitor desertification in pastoral areas are closely related to those used to monitor dryland farming and irrigation, since changes in resource use are critical in all three,sometimes competing forms of land use.

Mining can be used as an indicator of effects, where much land and other resources are affected in visible ways. Reclamation of mined lands in the United States is now required by stringent laws so that adverse effects should be temporary. Leases or financing to engage in strip mining involve the preparation of Environmental Impact Assessment statements, which describe the magnitude of the operation and the time required to effect rehabilitation.

Arid lands are increasingly valued for recreation as discussed elsewhere in this study. Calculating the dollar value of leisure-pursuit benefits and the costs in environmental terms is a new and challenging field for economists.

The quality of air and water also can be an indicator of changes taking place. For example, in some cases the growth of localized population and other activities in the Western States has been accompanied by a deterioration in local and regional air quality. A major problem has been the demand imposed on water supplies that often force agricultural lands to be retired either to housing or for the acquisition of water and groundwater rights. Reductions in groundwater levels and quality result in increased costs and energy consumption for pumping and treating in many places.

The economic uses of the land are accompanied by consequences which, in their long range manifestations, are only gradually being recognized. As better data are collected, baseline information compiled, and changes monitored, it will be possible to assess more accurately the ultimate consequences.

Table VI-1

Physical Indicators of Desertification

Indicator Classes	Source of Observation	Frequency of Observation	Background Data Variables
Soil Indicators Effective soil depth (changes indicate soil removal and sedimentation)	Ground and remote	Monthly - Annually	Rainfall Slope of land Soil texture Soil structure Wind speed, etc.
Soil organic matter	Ground (permits estimate of organic matter by inference from color)	Monthly - Annually	-
Crusts	Ground and remote	Monthly - Annually	-
Dust, duststorms and sandstorms	Ground and remote	Daily	Windspeed Temperature Soil moisture Geomorphology
Salinization and alkalization	Ground	Monthly - Annually	-
Water Indicators Water, ground depth and quality	Ground	Monthly - Annually	-
Water, standing open	Ground and remote	Monthly - Annually	Area, depth and turbidity
Status of drainage system	Ground and remote	Monthly - Annually	Water flow and sediment load
Other Indicators Relative reflectance (albedo)	Measured with satellite, air photo and ground instruments	Seasonally	Plant cover, soil surface, soil moisture, and soilcolor. Certain observations must be taken every time. Topo-edaphic setting. Antecedant rainfall.

Table VI-2: Biological/Agricultural Indicators (Revised)

Indicator Class	Sources of Data	Frequency of Observation	Background Data Variables
Vegetation			
Cover	production % of bare ground/ ground cover in dry season: aerial photos and observation, remote sensing	annually and seasonally	% of ligneous/ herbaceous plants % annuals/ perennials
Above-ground biomass	chlorophyll content: remote sensing production transects and quadrats: ground sample and lab analysis preservation plots	monthly/ seasonally 3-10 year intervals long-term measure short-term index	net assimilation climate soil type erosion below-ground biomass % of ligneous/ herbaceous plants
Key species	potential vegetation communities records, manuals ground observation of transects utilization levels with known animal populations	list compilation: 6 mos. - 1 yr. observation: seasonally	range ecological condition and trend the effect of utilization by different animals
Yield	grams of dry weight/square meter/year or season	annually or seasonally	short-term effect of fertilizers yield by species of plants in climax community and seral community desired on the site

Table VI-2 - Continued

Biological/Agricultural Indicators (Revised)

Indicator Class	Sources of Data	Frequency of Observation	Background Data Variables
Animal			
Key species of wildlife: frequency and distribution	arthropods small mammals and birds	annually or seasonally	relation and competition with domestic herds
Population of domestic animals	numbers and distribution of large and small stock based on livestock management censuses	annually or seasonally	carrying capacity of range; physical and vegetation indicators
Herd composition	composition of herds	annually or seasonally	physical and vegetation indicators determine diverse types of forage available. Variations in rainfall
Production	live weight of animals at market milk, meat	annual statistical review	purchase of supplementary cereals

Table VI-3: Social Indicators of Desertification

Social indicators described in Handbook on Desertification Indicators, modified for United States application.

- Changes in land use
    - Irrigation
    - Dryland agriculture
    - Rangeland
    - Mining
    - Tourism and recreation
- Settlement patterns
    - New and sudden expansion of settlement
    - Diversification of settlement
    - Settlement decline and abandonment
- Human biological parameters
    - Population structure and rates
    - Public health indices and nutritional status
- Social process parameters
    - Redistribution patterns
    - Income patterns

Table VI-4 Effects of a Water Supply Increase or Decrease of One Million Acre-Feet on Texas Statewide Economic Variables

Selected Sectors	Gain or Loss				
	Total Output*	Employment (Jobs)	Personal Income*	Tax Collections*	Value Added in Production*
Agricultural Crop Sectors					
Irrigated Cotton	543.67	14,861	156.84	51.01	310.54
Irrigated Food Grains	228.15	6,316	63.83	21.23	138.91
Irrigated Feed Grains	214.15	6,831	63.73	20.37	130.27
Other Irrigated Crops	330.13	11,491	89.80	34.54	209.96
Livestock Sectors					
Range Livestock	12.77	436	3.61	1.19	7.61
Feedlot Livestock	213.10	4,895	44.79	15.41	97.46
Dairy Farms	129.17	3,712	31.38	11.97	73.13
Poultry Farms	180.10	4,580	36.90	15.65	83.83
Manufacturing Sectors					
Processed Food Prod.	83.37	1,795	15.57	8.02	47.49
Agric. Chemicals	15.74	287	2.87	1.55	10.80
Petroleum Refining	58.28	997	10.80	5.61	36.95
Aircraft & Parts	79.89	2,051	22.61	8.39	45.59

*$ Millions.

Table VI-4 con't.

The Municipal Sector	6.18	244	1.78	0.53	3.91
Mining Sectors					
Crude Petroleum and Natural Gas	26.25	504	6.60	3.90	22.93
Other Mining and Quarrying	6.13	160	1.62	0.91	5.15
The Electric Svcs. Sector	12.14	262	2.48	1.97	10.83

*Federal, State, local, and Education.

Source: Texas Water Development Board, Continuing Water Resources Planning and Development for Texas, Vol. 1, May 1977.

Table VI- 5

Energy Costs for Various Irrigation Systems

(Diesel Fuel Only)

	Cost of Energy Per Acre	
	1977	1979
Traveling Big Guns	$28.16	$56.32
Center-Pivot	17.43	34.86
Skid-tow	14.67	29.34
Gated Pipe		
w/o Reuse	10.27	20.54
w/Reuse	8.71	17.43
Auto-surface	7.18	14.35
Drip-Trickle	8.89	17.80

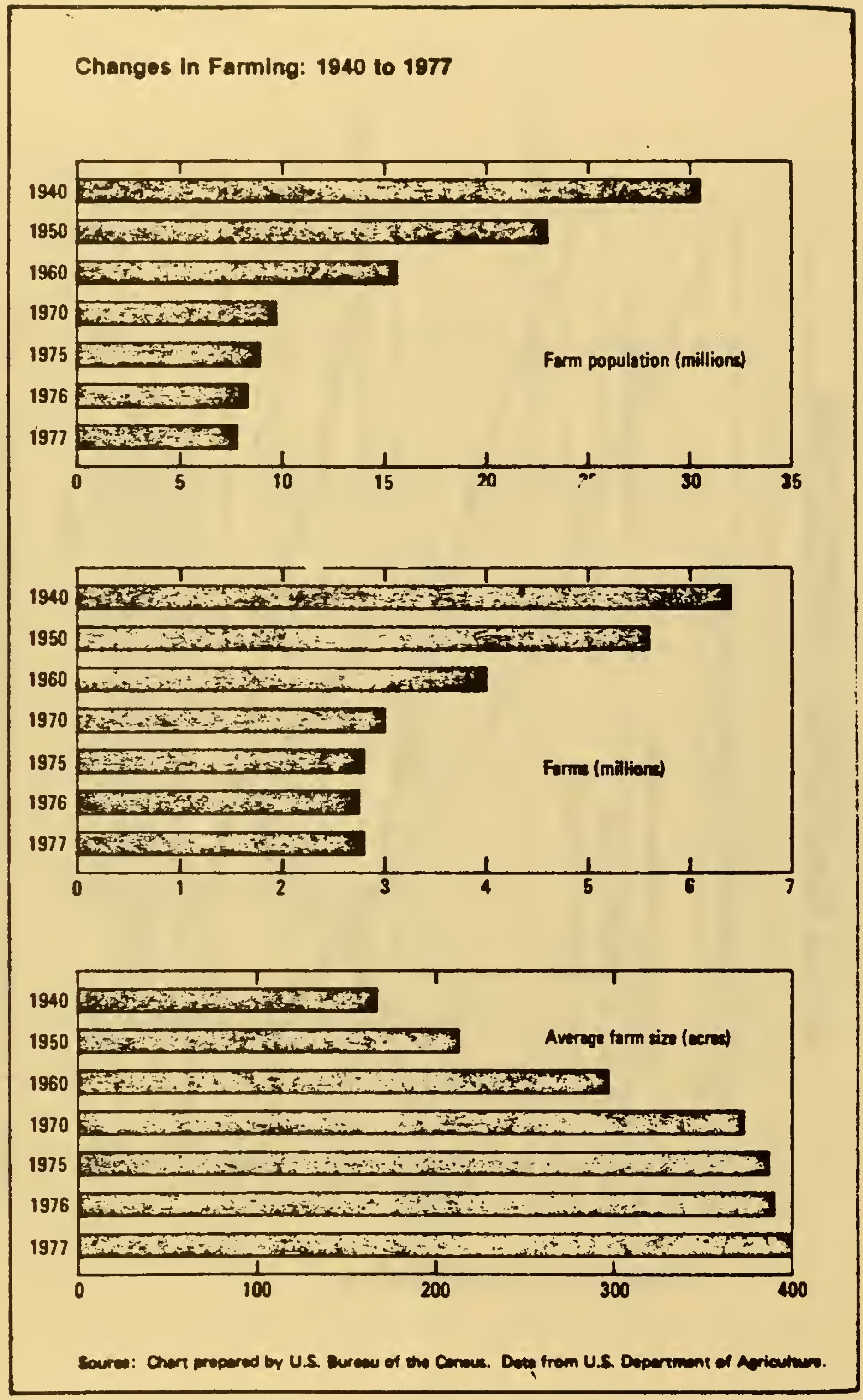
Based on: 100 ft. of lift from ground water reservoir;

12 inches of net water application;

$0.41 per gallon diesel fuel - 1977;
$0.82 per gallon diesel fuel - 1979.

Source: ASCE, Water Conservation Needs and Implementing Strategies, 1979.

Figure VI-1

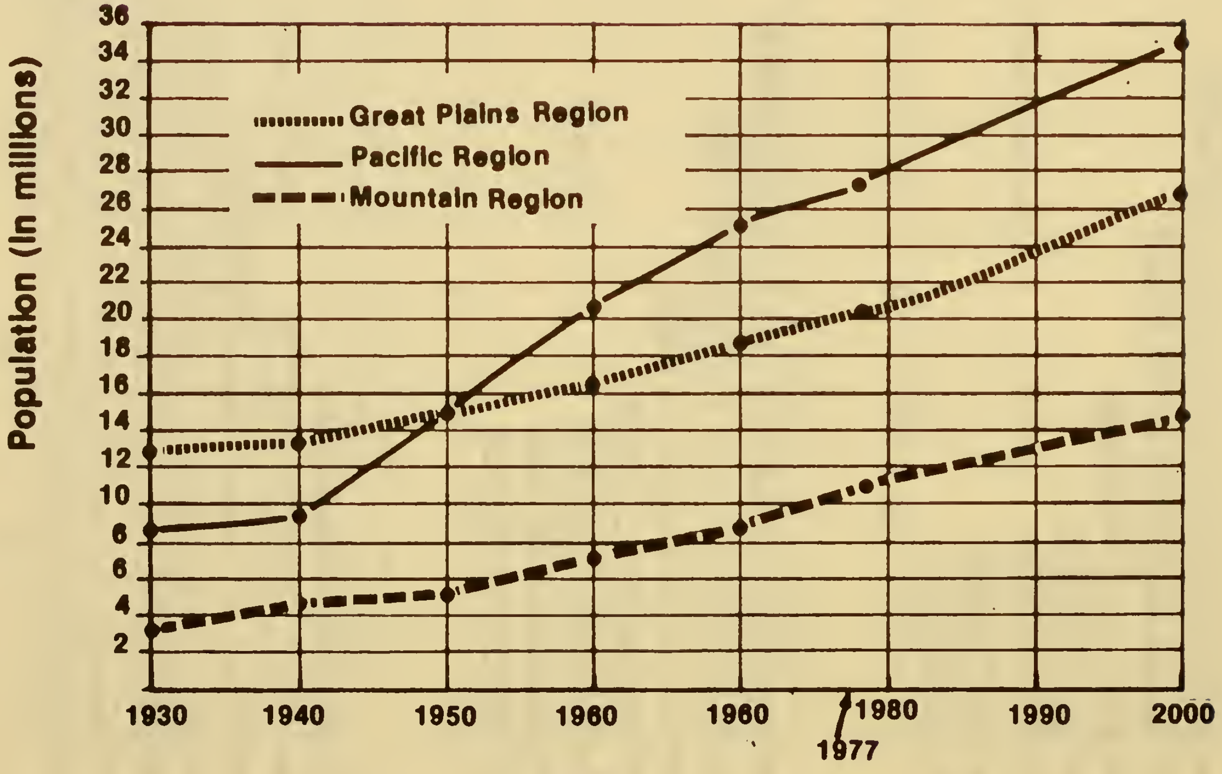


Changes in Farming: 1940 to 1977

Source: Chart prepared by U.S. Bureau of the Census. Data from U.S. Department of Agriculture.

Figure VI-2

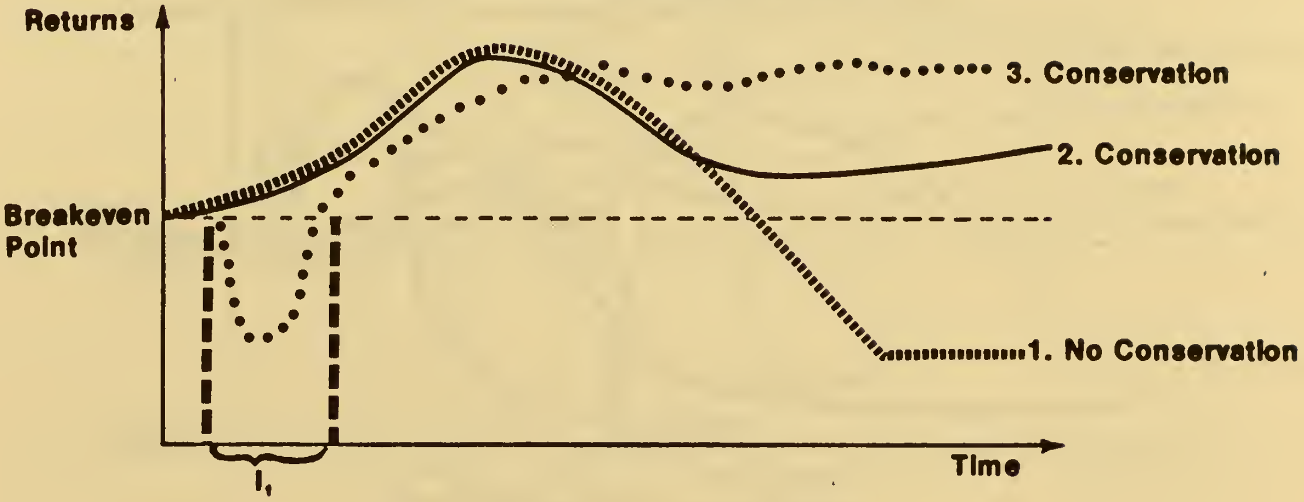
U. S·. Population - 1930 to 2000



Source: U.S. Bureau of the Census. Statistical Abstract of the U.S. 1978.

Figure VI-3

Returns from Dryland Farming with & without Conservation Practices.



▪▪▪▪▪▪▪▪▪▪▪▪▪ Curve 1: No Conservation - withdrawal from production

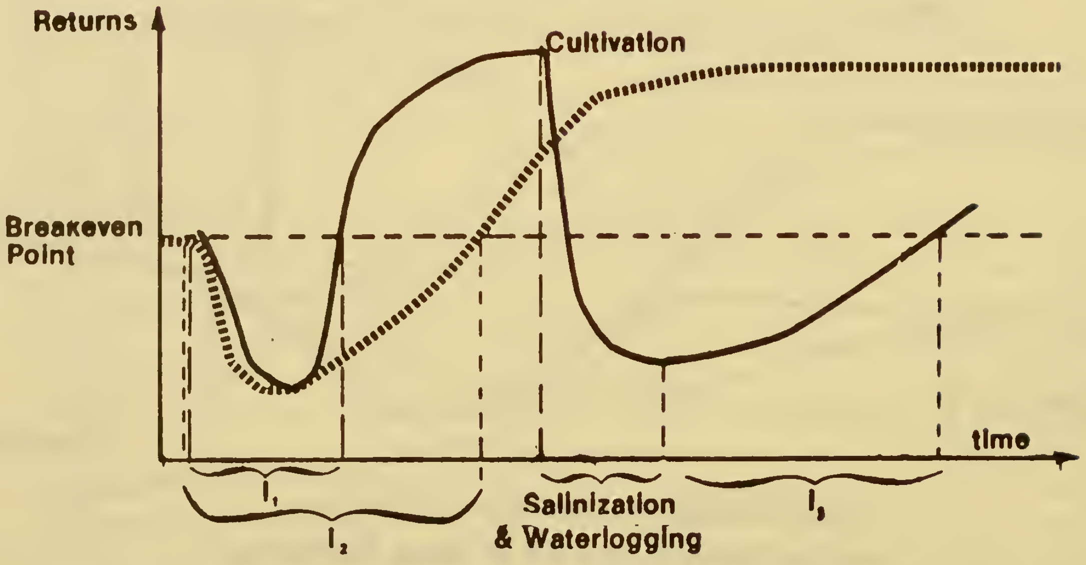
——— Curve 2: Conservation with investments in fertilizers, legumes, rotation contour plowing, etc.

• • • • • • Curve 3: Conservation with initial investment (I_1) in terracing, grassed waterways, fences, gully check dams, etc., plus above mentioned conservation practices

Source: Modified from A. Warren & J·K Maizel's, "Ecological Change and Desertification," 1977.

Figure VI-4

Returns for Irrigated Agriculture with & without Conservation Procedures



I_1 = Investments in dams, canals, roads, settlements

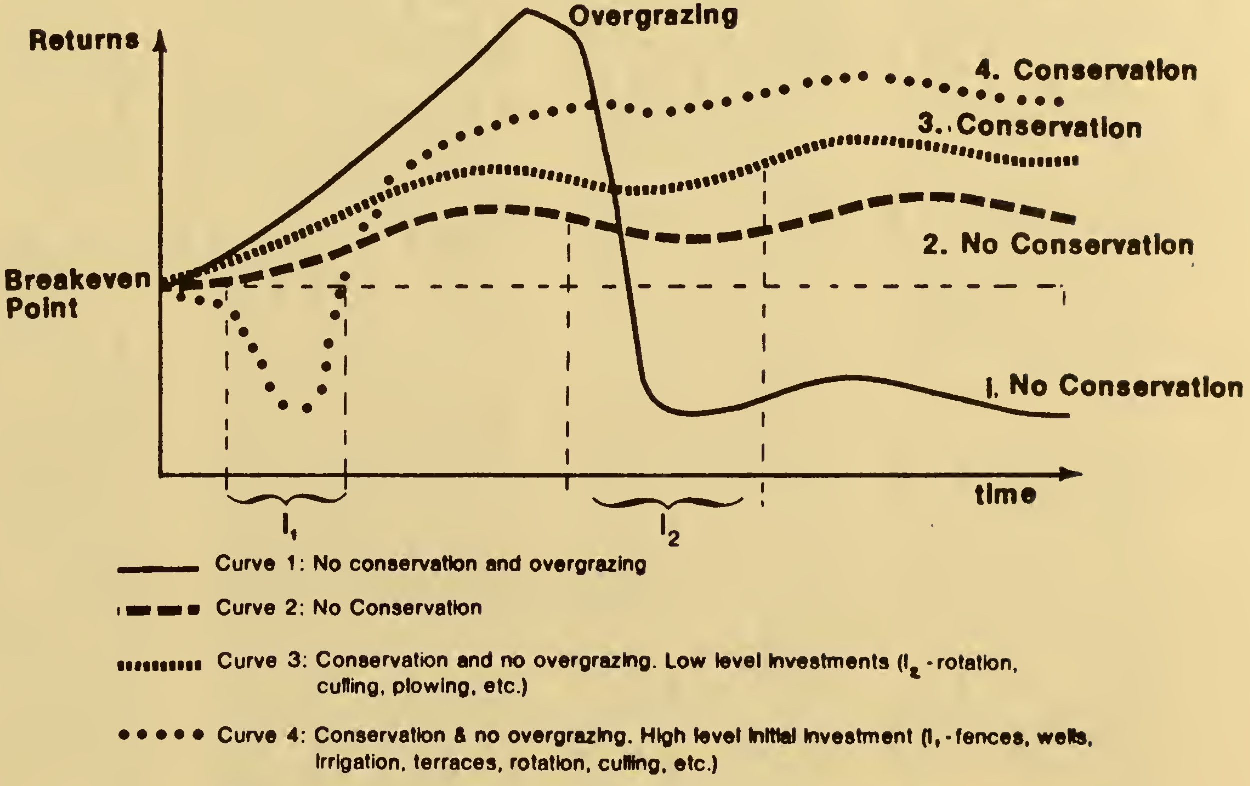
I_2 = I_1 and investments in drainage (conservation procedures)

I_3 = Investments in drainage, flushing, soil treatments (rehabilitation procedures)

VI.20

Figure VI-5

Returns from Livestock Activities with & without Range Conservation Practices (Response to Rainfall Included)



Source: Modified from A. Warren & J.K. Maizel's "Ecological Change and Desertification."

VII. Current Procedures for Identifying, Measuring, and Arresting Desertification: An Overview

Inventorying and Monitoring Systems

Specific national and international programs that relate to identifying, measuring, and arresting desertification are included in the Appendix under "Monitoring Programs." The purpose of this short text section is to provide an overview of the needs of a comprehensive system for obtaining and making use of data applicable to desertification while also discussing, in general, the limitations of the data system as it now exists. Using this as background, the current programs described in the Appendix can be evaluated as to how well each meets or could be used to meet the needs of a comprehensive data system.

Three compelling reasons for establishing a comprehensive data system applicable to identifying, measuring, and arresting desertification are: greater scientific understanding; increased public awareness; and the ability to take responsible, appropriate action. It should also be noted that a comprehensive system that would include a multidisciplinary, multi-jurisdictional assessment of the environment would have widespread applicability to resolving other concerns, such as the potential impacts on state revenues of shifts in population, and of changes in activities and the economic base due to desertification.

The foundation of a national data system should be a systematic inventorying and subsequent monitoring of the arid and semiarid lands of the Western United States that would describe the present condition of the basic resources (soil, water, flora, fauna, and air quality) and the nature and pace of changes in the quality of the environment. For this assessment, inventory is defined as a complete but static picture of the basic resources situation and the uses of each resource. Monitoring or re-survey, on the other hand, is a measure of the dynamics of change in the basic resources and the impact of the uses. Thus, the inventory provides a baseline against which trends observed through monitoring can be assessed.

Both inventory and monitoring can be complemented by comparison with any available historical data, and by incorporating data from other sources which can supplement the analysis of a particular region. Data from other sources, often measures of individual environmental components, can contribute to a larger assessment by identifying the distinct physical and cultural conditions that can combine to increase the proneness of a particular region or ecosystem toward desertification.

General principles governing the collection and use of data have been developed in the course of desertification studies. These include:

1) Quality assurance of the data to be maintained through standardization and constant auditing.

2) The several types of data collection - ground, serial, and aerial - must produce data which will be complementary and applicable at several levels from local to region.

3) Local participation in the collection and analysis process will assure more useful data and greater willingness to take corrective action where indicated.

4) Data to be formated and stored so that it is quickly available in usable form.

Efficient monitoring calls for a system that compiles monitoring and inventory data into a data management and informational exchange. Such a system will provide for:

1) The efficient retrieval of information in a user-oriented format.

2) The exchange of information inside and outside the system. Therefore, monitoring and inventory procedures should be designed to facilitate incorporation of data into a larger data base for land management.

Coordinating Environmental Data

Reliable and comprehensive monitoring requires coordinated application of advanced data collection, processing and analytical techniques as well as agreement among disciplines and jurisdictions on criteria and format to be used. Such information is essential to determine the extent of desertification and the nature, extent and indicators of effectiveness of possible remedial or mitigating actions.

A number of federal, state and local agencies have responsibility to provide for the multiple-use management, protection, and development of the arid and semiarid lands of the Western United States. These organizations are engaged in many actions involving various forms of data collection and monitoring. In many cases specific statutory authority governs the type and purpose of information gathering. Principal U.S. agencies and institutions responsible for monitoring and assessing the processes related to desertification include: the Departments of Agriculture, Interior, Commerce, the Army Corps of Engineers, and the Environmental Protection Agency. Recent progress in standardizing monitoring systems has been evidenced through interagency agreements to facilitate improved inventory information exchange and better state and federal coordination, as well as development of classification schemes. In addition, inter-

VII.2

agency working groups have been set up to identify areas of data gap or overlap.

Preventive, Remedial, and Control Systems

Available procedures for control of desertification are based on these elements: (1) appropriate legislation at the federal and state levels; (2) institutional arrangements setting up cooperative procedures for agencies with jurisdiction or expertise on environmental quality issues; and (3) the application of innovative technology for halting desertification processes and bringing about their possible prevention and abatement.

Steps are being taken to remedy deficiencies in data base standardization and exchange through a variety of Executive Orders, memoranda of understanding between government agencies and legislative and other directives which have resulted in the establishment of interagency and interdisciplinary task forces and liaison. The Departments of Agriculture, Commerce, and Interior have expanded activity in such areas as the monitoring of vegetation, consolidation of environmental data, and centralization of national mapping functions, respectively.

In the area of remote sensing technology, a significant recent development is the decision to proceed from the experimental Landsat phase to a fully operational satellite system with consequent assurance that timely data will be routinely available to federal, state, and local users. The interagency national High Altitude Photographic Data Base Program will obtain coverage of the U.S. in three years with high-quality photography. The high-altitude aircraft data base program and the global Landsat program will effectively complement one another. Another significant advance is the creation of programs to train state and local users in the application of these new data and to assure the quick availability of data at a reasonable cost.

Additional improved capability is provided by the development of the Domestic Information Display System, a major interagency program for storage, retrieval and display of environmental and other data on the United States.

Professor Dregne has observed (1978): "There is little likelihood that demands for a better life by a constantly increasing population can be met unless the technological component of development is expanded and improved (emphasis added)."

In the specific case of desertification control aimed at coping with land degradation problems, two general approaches utilizing technology exist: modification of the physical parameters of an arid region to permit greater biological productivity (e.g., importation of water); and the strengthening and promotion of actions which maximize efficient use of the arid lands (e.g., introduction of new varieties of drought-resistant plants).

The effectiveness of any applied technology is dependent upon the appropriate analysis, assessment, and consideration of trade-offs which takes into account the economic and environmental requirements--and people's expectations--of the affected region. It is only after the optimum required and expected return is established that the pertinent data can be assembled and manipulated.

The following partial listing of technologies applicable to arid region problems is divided arbitrarily into (1) high-level, high-cost technologies for modifying the environment, and (2) intermediate, adaptive technologies.

(1) Environment-modifying technologies

a. Interbasin water transfer facilities
b. Exploitation of new water sources by such devices as deep drilling
c. Desalinization plants
d. Climatic modification through prolonged cloud seeding
e. Major vegetation modification such as removal of phreatophytes

(2) Adaptive technologies

a. Cultivation of traditional desert plants such as jojoba
b. Genetic improvement of crop species to produce greater salt or drought resistance
c. Microclimate modification through such means as planting windbreaks
d. Local water runoff collection and storage
e. Improvement to local irrigation through drip and trickle water application system and tiling.

Limitations of Existing Procedures

Desertification processes can be halted and reclamation procedures initiated only if there is an accurate physical assessment of the processes involved, an estimate of the magnitude of the problem, and the location of specific problem areas together with information adequate to determine the potential for reclamation.

Desertification monitoring requirements for many kinds of data over large regions presently are difficult to meet at acceptable costs using conventional surveys. However, supplementing ground collection with remote sensing systems, combined with computers and electronic communications, shows promise for future coverage of large regions efficiently and economically.

Recent studies by federal and state groups have examined in detail domestic capabilities for environmental inventorying and monitoring. A general comment has been that quantities of specialized data are collected in a multitude of formats on specific environmental topics. However, to date there has been insufficient treatment of the data in an ecological or total environmental way. Coverage tends to be spotty, with concentration of data on areas of apparent greater economic potential. However, as a result of NEPA and other rulings, there has been increased emphasis on presenting information on areas in a total environmental form.

A Council of State Governments' report on Environmental Data and Monitoring Policy expressed two primary concerns: the need for improved coordination among agencies for collecting and using data; and, second, the need for improved responsiveness of federal data procedures to the needs of State users.

Another interagency task force, reporting to CEQ, reported major areas of concern as: coordination; quality assurance; cross-media analysis; budget consideration; and land use data issues. The report points out that inadequacies in data collection have resulted in: delay in federal projects; redundancy; and poor coordination with state programs. The CEQ report recommends a program to design long-term ecological measurements and improve resource data reflecting relationships between man's impacts and long-term natural environmental processes.

It appears that there is information on most of the arid and semiarid regions of the West. It also seems that there is an urgent need to better integrate the data and to extend it uniformly over wider regions.

VIII. Research Needs

Research is the process of producing knowledge and understanding. Without knowledge and understanding, the arrest and prevention of desertification would have little success. Research must be cost-effective and should provide not total, but sufficient knowledge to develop reasonable strategies to deal with the problem.

A systematic approach to a problem-solving situation, then, consists of: (1) a definition of objectives, (2) the specification of evaluation criteria, (3) the generation of alternatives, (4) the evaluation of alternatives, and (5) the selection of alternatives to be applied in solving the problem. In order to insure that each situation has a number of alternatives to choose from, a good understanding of the technical and scientific aspects is necessary. Institutional components must function in a manner that promotes selection of the best alternative. Proposed solutions should be evaluated in terms of future conditions. Finally, most desertification-related problems are highly complex in that they involve meeting the objectives of diverse groups and not all objectives are quantifiable to the same degree. Ultimately, the final choice of any action to alleviate the desertification problem must rest with the people. Thus, the decisionmaking process itself, one in which people are involved, needs considerable study.

To make intelligent decisions, the public must know the consequences of alternative courses of action. In addition to the economic consequences of the resource base use programs, the non-market costs and benefits of environmental protection and enhancement must also be evaluated, difficult as that may be.

Many unknowns cover many scientific areas which, once exposed, could influence man's capacity to live in and use the arid lands. The process of salt formation in soils, the process of evaporation from land surfaces, and the storage of water by plants are a few examples.

It is important to note that major breakthroughs are not necessarily required to make this type of research profitable. For example, water currently has a value of about $50 or $60 per acre-foot at the ground surface for irrigation in West Texas. Since approximately six million acres of land are irrigated, research findings that resulted in an average saving of one quarter of an inch of water per year on all irrigated land in the High Plains would conserve, each year thereafter, 125,000 acre-feet of water with a total value of $6 or $7 million. Surely, major breakthroughs are not required to effect water savings of this magnitude.

The Importance of Interdisciplinary Research

The whole desertification problem is composed of a large number of complex, multifaceted problems. These "parts" must be addressed for the purpose of selecting suitable procedures to deal with the total problem. In the particular case of arid/semiarid regions, the basic problem to be solved is how to manage the resource base so as to avoid desertification. Disciplinary research to help us to better understand the arid system is necessary, but the holistic approach, in general missing, is fundamentally important as well. For this purpose studies on the relationships between the physical and the social systems, and the organic and functional interactions between these systems, are greatly needed. Feedback mechanisms, ties between users and uses, and between events that affect desertification, can be better understood through a strong flow of communication and information between various specialists, users and decisionmakers. Some of the areas where interdisciplinary activities should focus are:

- Inventories of natural resources
- Cross-correlated research on the desertification processes
- Translation of data bank systems
- Development of new or superior methods for measuring cost/benefit ratios
- Long-range environmental effects of development of arid regions
- Demographic studies related to the regional carrying capacity
- Monitoring systems and indicators of desertification.

Throughout the rest of this section other areas of interest will be discussed.

Scientific and Technological

Some aspects of engineering and natural sciences (earth, atmospheric, climatic, biological sciences, as well as physics, chemistry, agronomy, hydrology, etc.) should be studied for their interrelated impacts on arid and semiarid lands. It is important not only to increase our knowledge of the scientific aspects of the resources concerned, e.g., water, but also that of the technologies that would provide better means for the development, use and protection of that resource.

Improved irrigation efficiency and conservation practices exemplify the potential benefits of research in desertification. With agriculture withdrawing some 90% of water in most arid regions, improved irrigation practices and methods can provide considerable savings in both water and energy.

For this example three broad spheres of research might be identified:

(a) Evaluation of the specific problems and their scientific, technological, economic and ecologic importance;
(b) Development of predictive models for the behavior of arid and semiarid lands under stressed conditions (natural and artificial);
(c) Establishment of the functional relationships within arid and semiarid land ecosystems and parameters needed to implement and operate the predictive models.

As with irrigated agriculture, other activities in the arid/semiarid lands that could lead to desertification should be researched for improvement.

Institutional and Legal

Research on institutional topics attempts to identify the formal and informal structures and processes of government and society which have either a legal or common usage base, and are generally accepted as authoritative in the society. Part of the identification process involves defining the role performed by the institution in the overall governmental process.

Legal and institutional aspects of research on arid and semiarid lands should aim at, but not be limited to, investigating the institutional, legal and social organizations that would permit efficient resources use. For example, work needs to be done on how we go about effecting changes in water use in arid areas, while protecting individual equity, the economy, and preferred modes of life with respect to energy development, agriculture, and municipalities and industries. There is also a need for a better understanding of arid lands institutions concerned with reducing risk (e.g., cooperatives, credit extensions, storage facilities), allocating scarce resources (e.g., water rights and systems of land tenure), and curtailing production in bad years (e.g., soil banks and price support systems). The operation of such institutions can minimize the probability of resource degradation and consequent economic and social dislocation. Criteria for evaluation of these institutions should include the flexibility of their response to the dynamic nature of arid environments and their contribution to the preservation of ecosystem function.

One example of potential benefits from such research is on the determination of the institutional arrangements that would allow the transfer of water during emergencies to mitigate the effects of droughts and desertification, since technically, such transfers are already possible. Water research needs involving institutional problems will provide information relevant to society's concern about this resource. And improved techniques for evaluating non-economic costs and benefits will allow governmental agencies and individuals to make more rational decisions in developing and allocating water resources when the quality of the land is at stake.

The following list of research topics associated with institutional and legal aspects that could be applied for the prevention and arrest of desertification exemplifies the need for and importance of research on these aspects:

- Documentation of institutional constraints and relative advantages: Are there inhibitions to choosing the most effective institutional arrangement? What is the functional relationship among local, state and regional entities? From a national perspective, what are the relative advantages of policy uniformity vs. diversity?

- Examining the transferability of water rights, particularly their effect on implementation of water conservation practices and policies, changes in water use and location of use, reuse and interstate/international issues: The means or method to effect water rights transfers should be included.

- Comparative and evaluative research of planning at the local, state, regional and national levels with the private sector to generate an appraisal of the government/private "mix," influence and effectiveness: What have been the consequences where land use planning has been carried out?

- Assurance of alternative institutional means for local institutions to take into account in their decisions extra-local resources and conditions. Examples:

  (i) There is a well-established legal doctrine that local (land) planning authorities must take into account extra-territorial consequences of their decisions. What would be the consequences of applying this doctrine to the institutions that control other resources in arid regions - stream flow, weather modification, ground water?

  (ii) Veto authority in the hands of higher government institutions, e.g., state agency having authority, with specific criteria, to veto decisions of local institutions.

(iii) Grants-in-aid.

- Analysis of institutional arrangements for regulating, funding, and protecting areas losing water in interbasin transfers. Such institutional arrangements in the United States have potential transferability to other arid areas in the world.
- Institutional arrangements for maintaining instream flows in areas of water scarcity.
- Identification of institutional arrangements that effectuate changes in use of water in arid areas while, simultaneously protecting individual equity, the economy and preferred modes of life; especially with respect to: (a) energy development; (b) agriculture; (c) municipalities and industries.
- Investigation and identification of Indian water and other resources rights and assessment of institutional ways for protecting both Indians and other users.
- Inquiry into the institutional arrangements for implementing Indian tribal control within the framework of existing agencies in matters of environment and energy.
- Cross-national and interstate study of institutional approaches to water scarcity.
- Assessment of the extent to which state power in land and water regulation is inhibited by the major federal presence in arid lands.
- Appraisal of institutional methods for effective coordination between resource planning and land use planning, in the context of arid conditions and in contrast to humid conditions.
- Review of institutional methods for effective coordination among national, state, and local resource management agencies.
- Identification of institutional barriers to land treatment methods for water quality control in arid areas.
- Assessment of existing and alternative interstate compacts and regional organizations.
- Examination of the applicability of interstate compact institutional arrangements for resolving international water problems.
- Evaluation of institutional arrangements for resources conservation on both a short- and a long-term basis.

- Research of institutional methods of minimizing damage from flash floods.

- Study of institutional arrangements for facilitating effective regional planning, both interstate and intrastate.

- Analysis of the effectiveness of present institutional arrangements for protecting long-term public interests in arid areas, rather than protecting short-term private interests.

- Assessment of the most effective scope of resource management institutions (local, state and national) in dealing with problems in arid areas.

Socio-Behavioral

The behavioral research related to the desertification problem places primary emphasis on the perceptions, attitudes, values and beliefs of individuals or groups; and effects of these factors on governmental operations. For instance, the attitudes, values and beliefs of people might be studied to determine the basis for various voting patterns, or to understand the operation of a large organization.

Research related to social-behavioral aspects should include, but not be limited to:

- Investigating public, private and combined (public/private) management schemes to determine more effective incentives for appropriate good management of natural resources/environment.

- Investigating incentives which create self-regulation, rather than government regulation, of water and other resources for more efficient use.

- Examining the roles that legislative, bureaucratic, and judicial decisionmakers play or could play in overall resource allocation decisions.

- Analyzing individual and group perception of arid/semiarid lands resource problems, the relation of these perceptions to the manner in which programs are being conducted, and the assessment of how people evaluate the potential return on and vulnerability of their investments as well as how they perceive their options.

In discussing the social and behavioral aspects of research on desertification, one should include:

- Attitudes, values and beliefs of individuals vs. the surrounding environment

- Incentives for self-control

- Public participation in decisionmaking

- Effects of the operation of governments (especially because of land tract ownership)

- Group participation and education

- Competing uses of adjacent lands.

In particular, the following list of 11 research topics associated with social-behavioral aspects (Caulfield, 1978) should further articulate the necessity and importance of this facet of arid and semiarid land research:

- Assessment of the extent to which public participation can/should be incorporated into resource allocation decisions

- Assessment of the nature and content of social and political conflicts between urban and rural interests in arid areas

- Investigation of the social and political consequences of changes, due to desertification, in dominant economic activities in arid regions, e.g., from mining and agriculture to manufacturing and tourism

- Analysis of the impact of regionalism in national policy issues debates, i.e., "Sunbelt" vs. "Frostbelt," energy-producing states vs. energy-consuming ones, etc.

- Investigation of incentive systems for resources conservation measures

- Assessment of the extent to which policies and values contribute to desertification of arid lands

- Assessment of behavioral effects of large-scale vs. small-scale technological responses to aridity and desertification

- Investigations of methods to effect short- and long-term changes in attitudes and values relevant to drought, aridity, and desertification

- Examination of impacts of special growth patterns in arid and semiarid climates, i.e., retired persons, fixed income groups, and energy development projects.

Sharing of Research Results

A distinct benefit of research results is the improvement of policy planning and management decisions at all levels of government and for all sectors of the economy. This particular goal cannot even be approached, however, if (a) decisionmakers are not mindful of the research, or (b) the process of translating research results into policy decisions is either omitted or neglected.

then,
The central question/is thus how to promote, foster and facilitate this translation of invaluable research results into policy decisions. One obvious group that cannot and should not be excluded from the translation process is the decisionmakers themselves. The term "decisionmakers" is used here in its generic sense to connote people at all levels of government and in all sectors of the economy. More research is needed in this context. It is worth emphasizing that research's role is to generate knowledge, not make policy per se.

Terms such as technology transfer, research development, and others are often used to express the need and desire of such a translation of research results into usable processed information readily available to decisionmakers. The documenting and translating of research results into layman's language, and the packaging and displaying of these results for their ultimate use by decisionmakers are both an art and science that must be further researched, studies, and improved upon.

Improvement in predictability of the transfer of technology is needed to bring about more effective use of technology, particularly among non-professionals. Obviously, some kind of training is necessary for nearly any kind of technology transfer.

Predicting and Forecasting

After designing disciplinary and interdisciplinary research programs where scientific and technical aspects of desertification and its prevention and control are examined, we may find these activities necessary but by no means sufficient.

Taking into account that arid and semiarid lands are especially susceptible to hydrological, climatic, productive and other extremes, the functioning of these regions necessitates research on prediction and forecasting activities as well. These research aspects should include improvement on predicting future climatic and atmospheric changes; predicting and forecasting weather information; understanding extreme events such as droughts, floods, heat waves, etc., by applying probabilistic and statistical procedures; developing water and vegetation resource forecasting methodologies to include population dynamics and all factors affecting the supply and demand of waters and vegetation; and predicting economic and financial impacts and changes. Forecasts and predictions should thus be structured into short-term problem-solving, and long-term research needs (on the order of 50 years ahead).

Policy Decisionmaking

The central theme of policy analysis is the investigation of governmental decisionmaking. As such, it seeks to identify the process by which public issues are recognized and the ways in which solutions are both devised and implemented. Decision analysis can be concerned with evaluation of implementation and the feedback of such evaluation into the decisionmaking continuum. Although it is a generalized approach, policy analysis is usually conducted in a limited area of interrelated problems and solutions, i.e., natural resource/environmental policy, forest policy, etc.

Research related to policy decisionmaking aspects related to the desertification problem should include, but not be limited to:

- Investigating the advantages and disadvantages and, if possible, the political feasibility of discouraging population migration to arid and semiarid regions; that is, curbing the long-term trend of population movement from the "Frostbelt" to the "Sunbelt"

- Developing more acute methods to identify, measure, quantify, and evaluate all commensurable and noncommensurable benefits and costs, including risk, in a multiobjective framework

- Assessing the effects of, and possible changes in, national environmental policies in arid and semiarid regions against a framework of environmental protection and arid economy maintenance.

Improved techniques for quantifying and evaluating non-economic costs and benefits will allow local, state, and federal governmental agencies and individuals to make more rational decisions in developing and allocating resources so as to prevent deterioration. Furthermore, an overall systems approach to the resource base management problems, with a thorough consideration of economic, environmental, quality, esthetic, quality of life, social well-being, and legal viewpoints will allow an informed public to better identify and select both optimal alternatives and consequences.

The following list of research topics associating institutional and legal aspects with decisionmaking, typifies the need for and significance of research on these aspects:

- Involve decisionmakers in research on policy decisionmaking. Mechanisms should be developed for presenting and packaging the various research results on policy decisionmaking aspects in a form usable and understandable by decisionmakers.

- Explore decisionmaking techniques for displaying, identifying, measuring, evaluating and integrating socio-envionmental (non-market values) and the economic objectives. In other words, social-environmental and economic objectives should be equally analyzed.

- Examine the distributional effects of certain policies related to soil and water conservation.

- Launch investigations that include the nontraditional scenario game-playing, such as

  - regulating irrigated agriculture;
  - assessing the effects of enforcing 160-acre limitation on irrigated acreage for federal reclamation projects;
  - limiting or stopping agricultural subsidies;
  - determining social resiliency and/or irreversibility of actions.

- Identify and evaluate types of federal and state policies which have been modified in response to arid conditions (e.g., The Homestead Act was modified in its application to the West by the Desert Land Act).

- Identify governmental policies unique to dry lands and evaluate their applicability for humid regions which have, or may have, problems of scarcity. There is already a tendency for Western water law concepts to move east.

- Assess the extent to which there is a need for, and existence of, an arid region urbanization policy.

- Examine the legal and political implications of a large-scale weather modification policy.

- Identify land types and land use patterns in arid and semiarid regions in order to establish the parameters for alternative land-use policies in the desertification-prone areas.

- Assess ground water policies, the extent of depletion, and its impact on the quality of drylands.

- Assess the political, legal, and technological feasibility of water reuse policies.

- Assess the efficiency of drought insurance as an alternative to investing in drought-proofing facilities (such as water storage reservoirs).

Public Need to Know

The sharing of research results includes not only consideration of technical and administrative communication but also the need for the public at large to have access to the information readily and in understandable terms. Alternative courses of action made possible by research efforts require a broad appreciation of environmental, economic and other impacts affecting a wide population. The decision process can only intelligently involve a wider segment of the public if constant attention is paid to the need for reporting results at different levels and languages, and by purposefully involving all communities of interest in the exchanges which lead to consensus.

Directions for Future Research (Basic and Applied)

Previously this section has described some aspects of the disciplinary and interdisciplinary research related to the desertification problem which should be undertaken. One question often asked is: Are we referring to basic or applied research? The distinction between basic and applied research is rather indefinite, and what may be basic research to one group may be considered applied by another. In the following, this distinction will not be made; and in general the basic and applied research described is considered necessary so as to:

- Achieve a better understanding of the impact of human activities on the structure and dynamics of arid semiarid biomes, activities that may result in desertification;

- Help solve the scientific, technological and managerial problems raised by the development and usage of the natural resources in the arid regions when the desertification hazard is present;

- Help in formulating natural resources policies that assess the special needs of the arid areas and that take into consideration the desertification;

- Facilitate the implementation of these policies by helping to attain specific objectives and keeping alternative options open.

It must be realized that science and technology have few ready-made, short-term solutions to offer.

Climate

Climate and Weather Variability Prediction

Latitudinal and longitudinal shifts in the air flow patterns of the Southwest can have profound effects on the climate. Such shifts are evidenced by drought when, for example, winter storms are diverted northward for extended periods of time. Although these synoptic patterns have been observed for many years, their mechanisms are not well understood. Research is needed in the following areas:

- Integration of atmospheric experiments to include the heating function, microscale, mesoscale processes, and the effect of vegetation.
- Determination of the "resiliency" or ability of water resources systems to cope with adverse climatic conditions. For example, interactive research is needed among climatological forecasters, plant biologists, and crop specialists for the establishment of production functions of plants as well as for estimating possible large-scale consequences of droughts and desertification.
- Research on deterministic physics-based climatologic modeling, and on climatic change. Such research may eventually lead to reliable climatic forecasts.
- Research should continue in an effort to gain basic understanding of man's potential impact on climate (e.g., the long-term effects of increased amounts of carbon dioxide in the atmosphere).
- The climatic trends and variations in ASAL, taking into account the micro-, meso-, and macro-scale processes.

The following questions need to be answered. Are there desertification trends? Complexities arise when one attempts to assess the trend, i.e., is the Southwestern desert growing or becoming smaller? A review of Southwestern history indicates that vegetation was much more dense 100 years ago than it is today. Reduction of vegetation density should change the albedo of the area and, subsequently, the climate, but has this occurred? If so, is the trend continuing?

The air quality in the large urbanized portions of the Southwest has markedly deteriorated in the past 50 years. The rapid increase in population in these areas, in general, has further exacerbated this problem. The influence of air quality on the climate could range from trivial to significant and could be manifested, for example, in changes in precipitation (positive or negative) due to the effects of air pollutants on weather systems, and changes in the radiation balance which could also affect precipitation and temperature.

Other important topics are wind erosion and dust storm causation and influences. Examples of questions to be addressed are: What are the trajectories and extents of dust storms? What are the main anthropogenic factors causing them? What is the effect of suspended dust on precipitation?

For planning purposes, knowledge of the probability of extreme weather events (floods, droughts) is also required. In some cases where data are limited, simulation techniques for generating synthetic time series are invaluable. With the inclusion of the response functions and the economic factors, the simulated time series can be evaluated in a decisionmaking framework.

Drought

The occurrence of major agricultural droughts in the past has in effect spurred on changes or adaptations in agriculture, and has promoted conscious efforts to raise the level of drought adjustment so that the next drought would have less impact. At each of the three last drought occurrences--the 1930s Dust Bowl, the 1950s and 1970s droughts--there was a flurry of activity and concern. Each brought a new or additional emphasis in adjustments. Each generated new research directions.

It has been agreed that some of the tools aiding drought research and drought mitigation that require further development include long range weather forecasting, remote sensing of land and water conditions, modeling interactions associated with plant growth, solar and wind energy development and studies of possible scenarios for future Great Plains and Western droughts. Even the well accepted and well proven physical tactics of drought amelioration may need a careful reassessment in view of the rapidly changing economics and politics of energy supply.

New scientific and technological tools should also be developed that will ultimately aid in drought mitigation strategies. These include:

- Improved weather and climate prediction on the time-scale of months and seasons;

- Improved assessments of land and crop conditions, to provide early warning of drought incidence and surveillance of drought severity;

- Integrative models of the interactions in soil, crop, weather, water supply, economics and other variables so that the potential impacts of drought (and other climatic stresses) may be screened as a planning aid.

- Scenarios of future droughts considering timing, duration, severity and extent of drought as a further guide in the design of research programs.

Some recommended research topics on agricultural droughts concern irrigation and water supply conservation. Full effective use of irrigation is encumbered by water losses from evaporation and transpiration and by inefficient on-farm application. Several lines of research would improve the situation, such as:

- Better methods of estimating future water demands;

- Less expensive means of lining existing canals and ditches to reduce seepage loss;

- Increased effectiveness and reduced cost of retardation of evaporation by such techniques as monomolecular films;

- Various alternatives, and the full environmental effects, of reducing transpiration losses from phreatophytes by chemical control;

- Increased water user efficiency;

- Crop-yield water requirement relationships;

- More efficient water application systems;

- Additional research on managerial models of water use; and

- Clearer definition of the nature of deficiencies in water laws and institutions, and a development of alternative models of water supply management to overcome these deficiencies.

The recommended research topics that follow convey a broad perspective which could lead to flexible modes of adjustment to urban drought problems. Much of the research for agricultural droughts is of direct benefit for urban droughts also, particularly water supply protection, weather modification, land use regulation, and prediction and forecast research. Some research activities specific to urban droughts are:

- Desalination and water recycling technology
- Improving conventional water supply systems
- Altering water demand
- Reuse of water
- Social problems of water reuse.

Soil

Soil Salinization

Soil salinity is a predominant characteristic of arid and semiarid lands. Although considerable work has been done on soil salinity, and the technology is generally well understood, more research is needed in selected areas. One major research issue is how to encourage acceptance of practices to avoid salinity.

The following selective research needs to be explored:

- Proper management of both cultivated lands and wildland watersheds;
- The effect of agricultural runoff on receiving waters;
- Gradual salinization of soils, disposal of salts, and soil rehabilitation;
- Efficient and economic irrigation management strategies to reduce the detrimental effect of saline irrigation return flow from agricultural lands.
- Effects of soil salinity on microbial mediated nutrient transformations such as nitrogen and sulfur cycling.

Reduction of Erosion

Research in soil erosion should be tied directly with the soil potential concept of land use planning, and include climatic conditions as well. The soil potential rating (McCormack, 1974) is the ability of a soil, aided by modern technology, to produce or support a given structure or activity.

More information is needed on erosion control such as:

- Land surface condition
- Wind barrier vegetation
- Chemical soil surface stabilization
- The mechanism by which soil particles move out of the normal soil structure into rills and then into gullies.

Research is needed on the reclamation of swamplands in and around semiarid lands.

Land Reclamation and Soil Loss Equation

In reclaiming and rehabilitating land in arid/semiarid regions, some specific problems are present that could lead to desertification. Some of the factors that should be considered in designing soil-related research are:

1. Soil water (drainage) - water movement through and over the soil including infiltration, permeability, water holding capacity and their relation to storm drainage, plant growth and sewage disposal.

2. Soil slope - measured by degree of slope and shape.

3. Soil erosion - the present condition during overland flow and susceptibility to future erosion.

4. Soil depth - depth to bedrock and other material difficult to excavate.

5. Soil stability - engineering properties that determine suitability for subgrades, sanitary landfills, etc. Shrink-swell characteristics and presumptive bearing values which affect foundations are also included.

6. Soil wetness - usually expressed as depth to water table, stream overflow and collection of surface runoff.

7. Soil permeability - capacity for movement of water through the soil.

In general, soil water quality is not specifically spelled out even though adverse quality parameters, e.g., salinity, is included in the final assessment of land use. One example of other problems present in these surveys is that data from alpine terrain is interpreted as using the same criteria as that from such diverse areas as river bottoms or rangelands. In general no consideration is taken in integrating into the interpretation for land use planning such important regional factors as climate, atmospheric diffusion in complex terrain or atmospheric temperature gradients, all of which impact on the ultimate development of a region.

Refinement of the soil potential concept of land use planning to include climatic considerations with reference to semiarid mountain terrain is also recommended. This rating in general integrates the yield or performance level and the difficulty of applying treatments to overcome or minimize the effect of soil limitations.

At present no widely supported methods exist for measuring soil loss from arid and semiarid lands. The Universal Soil Loss Equation (USLE) has been used but its derivation for small farm watersheds makes it suspect when applied to semiarid mountain terrain and its mesoclimate. Improvement of the USLE would require research on the rainfall factor (R), the slope-length factor (SL) and the erosion factor (K).

The mesoclimate and soil factors should be studied jointly in terms of soil erosion and stream sedimentation which is a major water pollutant. Research sites should include wildland watersheds, lands after timber cutting, oil shale spoils and strip mine overburden.

Water

The allocation of a scarce resource, water, is viewed by scientists as the center of practically all the issues generated by competing demands and demographic changes in the dry areas. Nevertheless, increased understanding of nature's hydrologic systems is necessary for successful resolution of some of these problems and avoidance of others, specially where desertification may occur or is present.

While the major emphasis of research in water resources management has in the past been directed toward methods for increasing water supply, such as desalinization and weather modification, this approach should be modified. Emphasis will have to be shifted towards the conservation and protection of water resources, specially in water-short areas.

Some general research objectives presented in this section are to:

- Develop methods to increase irrigation efficiency.
- Conduct studies on hydraulic properties of aquifers - Natural recharge - Infiltration - Contamination problems.
- Develop hydrological simulation models capable of integrating surface and ground water quantity and quality characteristics.
- Conduct studies on augmentation of water supplies through water reuse, salvage of diffuse and emphemeral desert basin runoffs, water importation--problems and impacts.
- Develop methods for calculating minimal water/energy budgets for agriculture and other land uses that permit optimal use of resource base and avoid the hazard of desertification.
- Conduct long-term studies to determine the impact of lesser quantities of water on the soil and the timing of water for each plant species.
- Develop methods to control and utilize tailwater more effectively.

Ground Water

Severe quantity and quality problems are facing ground water systems throughout the country, as ground water resources are contaminated and wells are closed or depleted. It is noteworthy that ground water is a major source of water supply in the Western and Great Plains States. There is inadequate technical and related data about ground water resources--information needed to make sound decisions about regulations and management. Much work needs to be done to fully understand the physical and chemical processes involved in the changes of water quality occurring within the aquifer.

Studies are needed on water mining; artificial recharge programs; well and playa lake management and modification; potential for pesticide and fertilizer contamination of aquifers; assessment of diverse irrigation and cultural practices.

Research is needed on natural and induced recovery of a contaminated aquifer; waterlogging of soils and its effect on salinization of ground water; impact on aquifers of underground storage of liquid wastes and excess surface runoff; recharge of treated municipal wastes into shallow and deep aquifers, and pressure buildup consequences.

Other areas needing research are: ground water conservation and reuse practices, their social and economic effects; demand control methods for diverse uses; management alternatives assuming ground water as a non-renewable resource; equity in multiple use of scarce ground water and total water resources.

Research should also explore the augmentation of ground water supplies through salvage of diffuse and ephemeral desert basin runoff. The use of such artificial means would minimize diffuse system losses, maximize use of aquifer storage capacity, and extend the developable ground water supply.

Studies are needed on the feasibility for enhancement of ground water recharge in desert valleys through artificial means to minimize diffuse system losses, maximize use of ground water reservoir storage capacity and extend the developable ground water supply.

Water Supply and Demand

The discussion in this section includes water quantity and quality considerations.

Conservation: It has been suggested that negative incentives constitute the greatest deterrent to effective water conservation. These negative incentives are, for the most part, legal or institutional. Research is needed to determine the extent to which these negative incentives are valid, and to suggest mitigating alternatives. Presently, the only method used to regulate the amount of ground water pumped on the Texas High Plains, for example, is well spacing. Legal and institutional research can provide alternatives which may better suit the interests of High Plains residents. For example, subsidization practices should be examined.

Another suggested research topic is to investigate the institutional, legal and social organizations which would promote efficient water use - including the emergency transfer of any and all water supplies within basins or projects. Research needs associated with water importation include inventories of the water needs of areas of origin and use, multiobjective analyses, environmental impact assessments, artificial recharge investigations, energy impact studies, and institutional framework analyses.

The social-behavioral aspects of demand management need to be studied. What are the incentives for demand management? What are the cumulative effects of pricing, land use managment, legal changes, institutional changes, conservation and the increased use of reclaimed waste water on the long-term demand for water?

Some of the conservation-related research topics are:

(a) Case studies of demand management by pricing, metering, education, regulation, etc.

(b) The new phenomenon of limiting growth (urban or agricultural) according to the criterion of water availability.

(c) The way in which various states look at evaluating demand within existing laws.

(d) Variability of water availability, and the likelihood of immediate institutional response to changes.

(e) Case studies of the recent drought in the American Southwest in terms of what worked and what did not.

(f) Possibility of extensive use of anti-transpirants for plants.

(g) Possibility of genetically improved varieties of arid and semiarid plants.

Demand Growth: Arid regions are becoming more crowded, natural resources more intensively used, and budgetary funds less available. More substantive information regarding the relationship between population dynamics and available water resources would permit more intelligent decision-making regarding optimal population size for a given area.

The social-behavioral aspects of the net migrations to arid and semiarid lands require study. What are the incentives for and barriers to this movement (e.g., employment, retirement)? Are there current governmental programs which, in a de facto sense, encourage such migration (e.g., defense spending, energy development)? Can these migrations be stopped by communities which limit their populations?

Water resource forecasting methodologies should be improved to include population dynamics, and all factors affecting water demand and supply.

Water Reuse

Water reuse can be an effective method for meeting some of the increased demand on limited fresh water supplies. In arid and semiarid parts of the country, in fact, the clear need simply to reclaim and reuse water once is being surpassed rapidly by the necessity to subject water to multiple reuse. While technological advancements necessary to reuse water effectively have been made in recent years, deficiencies still exist. Most technological innovations have been concerned with the reuse of wastewaters for industrial purposes, with little regard to agricultural reuse. Agricultural reuse systems should be a topic of intensified research and investigation. Economic analyses should be undertaken to determine potential savings through reuse in terms of short- and long-range benefits, as well as savings in treatment costs and benefits from nutrients contained in wastewater.

Probably the greatest deterrent to water reuse that exists today is the question of risk associated with health effects. In addition, because of quality deterioration, water cannot be reused indefinitely in a closed cycle. Methods to treat or dispose of water no longer reusable must be found. Such methods must be environmentally sound and economically feasible. Of particular importance to studies involving agricultural reuse is the quality of the water to be reused. For example, it is important to know the effect that certain contaminants, especially organic chemicals, will have on crop productivity and soil quality. Specifically, the fate of potentially harmful organic chemicals needs to be documented.

Flora and Fauna

Stressed Ecosystems Studies

Desertification, drought, flash floods, and dust storms are some of the stresses on arid/semiarid areas. Not much is known about the biota responses to stresses, nor the rate of recovery from a single event and/or combination of events. Also, an increased effort must be made to define the basic functional responses of crops, plants, and animals to weather and climate so that we can improve our present systems of crop, range, and livestock management. It is important as well to better understand the impacts of diverse land uses, e.g., dry farming, grazing, mining, urbanization, etc., on the arid-semiarid biomes, and how desertification may result from these impacts.

Acid Rain

This is a special stress on the arid ecosystems, that is increasing in importance, and should be considered. Acid rain, in any of its many compositions or forms, causes deterioration of vegetative cover, and in this fashion may initiate and/or contribute to desertification.

It should be emphasized that "acid rain" is simply shortened terminology to identify the pollutants, both soluble and insoluble, deposited from the atmosphere. That term has been used because the most obvious deleterious effects in the eastern United States have been attributed to the H^+ ion in precipitation. Other effects, at least as serious, may be due to mercury, cadmium, fluoride, lead and various organics.

Increased acidity in rain has been observed in localized areas in the Midwest and along the West Coast, and the potential exists for acids and other pollutants in Colorado, Wyoming, and other nearby states from full development of fossil fuels. The President of the U.S. addressed the problem in a statement of August 1979, asking for a 10-year program of research on the cause and consequences of acid precipitation. An interdepartmental Acid Rain Coordinating Committee has been established by the President to plan and manage the program. The Interior Department has responsibility for many of the areas in which an impact can be expected from "acid rain."

Extensive regions of the Western States are both sources and receivers of acid rain impacts. Arid lands include those upon which existing and future coal mining and power production activities lie, which are great sources of particulates, aerosols, and gases. On these lands timber and forage production and other

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resources may be sensitive targets of atmospheric deposition. In addition, the long-range transport of acid rain constituents from sources in arid and semiarid regions may have adverse impacts several hundred miles downwind from the source.

Some of the research needs in this area are:

- Identification and measurement of the anthropogenic and natural sources of emissions causing acid rain in the Western States.
- Physical and chemical properties of atmospheric transport in dry lands.
- Processes and composition of wet and dry deposition.
- Effects of acid rain on the organic, inorganic, and nutrient components of soil in arid/semiarid biomes.
- Biologic effects of acid rain on vegetation: crops, forests, rangeland, bacteria, fungi; and on animals: wildlife, domestic animals, and humans.

Salt-Resistant, Drought-Resistant Plants

There is a need for rethinking and reevaluating the traditional approach to salinity, which has been devoted almost exclusively to environmental manipulation. Most needed are the addition and vigorous application of new, biological and, specifically, genetic dimension to research and development dealing with salinity. Some of the topics for research in this area are:

- Methods for increasing the existing germplasm collections through the addition of salt-tolerant species and varieties.
- A judicious choice of promising species which (a) are of actual or potential importance as sources of food, fodder, fiber, medicinal or industrial materials, or biomass for energy, and (b) have an evidenced genetic potential for salt tolerance.
- Basic research into the mechanisms of salt tolerance and sensitivity.

Efforts should be made to develop plant-growth stimulation models with a data base sufficient to lead into recommendations for optimal water use under a variety of conditions: e.g., unlimited water availability, limited water at various growth stages, limited water application rates, drought conditions. The models could be used to determine:

- Physiology of plants and crops native and/or adaptable to arid and semiarid lands (using high salinity and natural water for irrigation and various irrigation methods).
- Market values of arid and semiarid crops and development of appropriate technologies to make production of such plants economically attractive.
- Land classification schemes to define compatible land-plant-animal-climate systems.
- Ecological sensitivity of arid lands to temporary and persistent weather changes.
- Climatic and hydrological effects of agricultural land use (with emphasis on the effect of introducing native and non-native species to arid and semiarid lands).
- Drought tolerance and protoplasmic qualities in mesophytic higher plants.
- The mechanism by which some plants survive very high temperatures leading to collection and breeding of heat-tolerant varieties of valuable plants.
- Methods of adapting plants and animals to aridity.
- Methods for collecting, propagating and farming rare and endangered species.
- Reforestation and rehabilitation of semiarid lands.

Wildlife and Grazers

When desertification occurs, animals are affected as well as vegetation, as discussed in chapters IV and VI. Some areas of fauna research may include:

- Transplant and propagation of endangered species.
- The extinction process of endangered species through time and the induced extinction due to desertification.
- Development of economic inventory techniques for rangelands.
- Development of classification schemes for rangelands.
- Studies on succession on rangelands.

- Species of grazers that could survive in distressed ecosystems.
- Grazing tolerance of distressed ecosystems.
- Game ranching alternatives to domestic livestock.
- Introduction of exotic species in stressed ecosystems.
- Impact on domestic and wild animals of the dewatering of streams.
- Vegetation management to minimize herbivory.
- Quantification of impact on yield, succession, watershed properties.
- Integration of knowledge of grasshoppers and locusts and their effect on desertification.

Population Dynamics

Growth Patterns

Drylands native populations evolved social systems incorporating methods of resource use that maintained them in dynamic equilibrium with arid environments. With the European colonization of the New World and with the conquest of the West, new modes of coping with a hostile environment were applied. The United States has evolved highly integrated economies and transportation networks, and dry areas populations have become somewhat less vulnerable to the effects of desertification and drought. In such moderate- or low-risk situations, the climate and relative uncrowdedness of arid lands have encouraged movements into drylands. As stated in Chapter V, a net migration from the Frostbelt to the Sunbelt of the nation is taking place that is taxing, in some instances heavily, the resource base of certain portions of the Western States. Also, the population and economic shifts from farm to urban-related activities and the changes in land uses have resulted in the local abandonment of field systems, including terracing, small, ephemeral stream dams, and primitive irrigation networks that, in some cases, can be considered a factor in desertification (Kates et al., 1976). While excessive population growth increases demands on the resource and may lead to its impairment, some as yet unknown number of people is needed both to maintain the labor-intensive modes of adaptation that insure long-term productivity and to transmit knowledge of such adaptive technology to other generations.

While the American Southwest appears to represent a successful example of maintaining large populations in arid zones without resource impairment, some symptoms of declining productivity may suggest that the area may instead have achieved a tenuous, short-term environmental equilibrium. Should the high costs of securing or maintaining water supplies generate demands from the rest of the United States that Western resource development "pay its way" in higher levels of agricultural and energy production, the degradation of resources and destruction of social systems so evident in the Third World nations could conceivably be triggered in many areas, as well as accelerated in the few already desertified regions. Some of the topics that need to be studied are:

- The traditional methods of coping with the inherent variability of arid lands, including strategies for dealing with risk. Findings should inform current policy and enable better prediction of the consequences of altering or eliminating traditional methods of coping with aridity.

- The attitudes and perceptions of populations which are the target of arid lands policies. The research should include an assessment of how people evaluate the potential return on and vulnerability of their investments, as well as how they perceive their options. The question of what motivates successful local participation in development and anti-desertification efforts should also be addressed. A better understanding of how people perceive their risks in arid lands would contribute to the development of more sensitive policy.

- The dependence, if any, of the social systems on institutional supports such as federal subsidies.

- The effect on the social systems of increasing urbanization.

- The economic and environmental costs of, and impacts on, the arid regions for securing water, energy, and raw materials for growing urban centers. Example: water resources for the city of Tucson come at the price of retiring farms around the city.

Economic Dynamics

Increased recognition is given to the need for making the best long-range use of natural resources - an approach that often conflicts with the conventional economics of each individual or entity for maximizing returns. In the case of dry lands, the recognition of the limitations of the system and the hazard of desertification fosters the interest in conserving, sustaining, and enhancing renewable resources of the land - its fertility, its stock of vegetational and wildlife species, and its access to water. It is also recognized that these resources must be protected from irreversible damage. Another concern related to maximizing the life-cycle value, rather than the short-term value, of non-renewable resources, such as ground water without present natural recharge, by managing their extraction in a way that will ultimately produce the least waste, and best protect them from avoidable damage. These concerns and interests have different research aspects related to different time horizons and to diverse policy approaches to the trade-off between long-range and short-range values.

This approach to research on economic dynamics may be subdivided according to whether they are resources of the arid region itself, or are obtained by exchanges of resources or services with other regions. In a regional approach to research needs, this distinction will separate problems whose solutions may be sought within the region, from those whose solutions must necessarily involve interactions with other regions.

Another tendency of current thinking is toward explicit recognition that traditional economics emphasizes short-range dollar values, which results in treating the returns of extracted resources as current income rather than as withdrawal of capital. Today, advanced thinking is directed toward a broader framework of valuation where prices of extracted non-renewable resources are predicted on the cost of replacing them with renewable resources.

A final distinction can be made along the line that connects urban-industrial concentration with highly dispersed uses of land such as livestock. Among dispersed uses, livestock raising is the most important, the success of which depends, in part, on the special ability of stock to forage over a very large area of the land's natural resources - its sparse vegetation. Nearly all activities based upon imported resources tend to be concentrated in very small, densely populated regions, with special characteristics of amenities.

While typical cost of water used for irrigated agriculture may vary from $5 per acre-foot to $50 per acre-foot, water used for domestic purposes costs approximately $120 per acre-foot; water used for secondary oil recovery purposes is rated at a value of approximately $600 per acre-foot. Therefore, if economic forces alone were to determine where adjustments in water consumption were to be made, agriculture and its supporting industries would bear most of the burden. Studies to estimate the impact that response to such water values would have on agriculture in arid and semiarid lands, and to investigate means of mitigating adverse impacts that would certainly accompany any shifts from agriculture are needed. Similar studies on other resources affected by desertification and their shifting values are needed as well.

Energy costs, rather than declining water supplies, may markedly reduce irrigation in the West. For this reason, it is urgent to conduct studies aimed at solving the problems of the cost of energy, increasing the efficiency of irrigation, or determining other alternatives which will lessen the impact of drastic increases in the cost of energy. Research is also needed to evaluate alternative energy sources for powering irrigation wells. Such alternative energy sources will include solar, wind, and biomass - all of which are frequently associated with arid and semiarid lands.

The present average cost of water for irrigation varies from $5 per acre-foot to $50 per acre-foot, whereas it has been reported that the energy sector is willing to pay a much more substantial price. The price differential is likely to cause a major shift of irrigation water to energy-related activities. The corresponding socioeconomic impacts of this trend and the associated local and regional economic tradeoffs should be studied.

Other topics to be studied include:

- The implications of developing and exporting resources of arid lands for utilization outside arid regions that would not contemplate rehabilitation of impacted areas.
- The costs and benefits of applying national environmental standards to arid lands.
- The development of methods to better quantify and analyze the losses due to desertification.
- The development of methods to measure the benefits accrued from preventing and arresting desertification.

Agriculture and Other Land Use Interactions

While much research has been conducted on cultivation practices, more research aimed at conserving soil quality and soil moisture is warranted. The frequency, depth and optimum times for plowing to conserve the greatest amount of soil moisture and nutrients, and maximize crop yields need to be further studied. In like manner, the effectiveness of different types of terracing practices in utilizing available precipitation requires evaluation, particularly in view of rapidly changing energy costs.

"Conventional wisdom" is that cotton and grain sorghum are the best money crops to raise in the South Plains, for example. This may no longer be the case in the immediate future. Experimental plots should be utilized to investigate crops which grow well and produce high yields with less water, to develop drought-tolerant genotypes, or to find "big money" crops which could, conceivably, be grown in smaller quantities on fewer acres, and still generate the same dollar volume as crops presently grown. If these research results dictated cropping changes, then improved or different methods of financing, marketing, processing and transportation might need to be developed. Optimization of such developments would, likewise, require a substantial research effort.

Other topics of direct import for desertification problems: Farmland depopulation problems; impacts of changes in land use practice on marginal lands; validation of new technologies in minimum tillage cultivation; energy-water budget in agriculture and other activies; impacts of salinization problems on agricultural activity.

Indian Concerns

Indian concerns should be considered in any research of arid and semiarid lands, because of their historical perspective on the land, their unique legal-institutional rights, and their special needs.

One research area would be assessment of past irrigation projects on Indian arid and semiarid lands, to determine their relative success or failure. Research should also be conducted on crops which may be of interest on reservations, such as jojoba, guayule, mesquite, and saltbush for animal feed. The water quantity/quality requirements of each should be examined, as well as the market potential.

Studies should be conducted on the traditional methods of coping with the inherent variability of arid lands by the native populations, including strategies for dealing with risk, and the modes of adaptation evolved. Other research activities could be undertaken to:

--Study the attitudes and perceptions of Indian tribes which are the target of arid lands policies. The research should include an assessment of how the different tribes evaluate the potential return on and vulnerability of their investments, as well as how they perceive their options.

--Survey and evaluate the performance of arid lands institutions concerned with reducing risk (e.g., cooperatives, credit institutions, storage facilities), allocating scarce resources (e.g., water rights and systems of land tenure), and curtailing production in bad years (e.g., soil banks and price support systems). The operation of such institutions can minimize the probability of resource degradation and consequent economic and social dislocation.

--Evaluate the mechanisms for placing and maintaining arid lands problems on government agendas. Policies formulated under crisis conditions may focus on symptoms rather than underlying causes, and the political atmosphere conducive to policy making can quickly disappear. This may apply to Indian, public, and privately owned land.

Multi-Objective and Multi-Attribute Analysis

By virtue of their special characteristics, arid and semiarid lands call for a radical improvement in what is known as "economic analysis." Research is needed to develop decision-making methodologies and approaches for identifying, quantifying, measuring, evaluating and integrating non-commensurable objectives and attributes, associated with both the social and environmental (non-market values) and the economic considerations. In other words, social and environmental impacts should be considered equally with economic impacts.

We should carefully examine the concept of cost-benefit analysis when used as the sole criterion for excellence. The importance of multi-objective analyses, where all objectives and attributes of the resource base are considered, should be recognized, especially in the case of dry lands where the desertification hazard is high.

It is an acceptable notion that all benefits and costs (monetary and non-monetary, commensurable and non-commensurable) should be considered in such an analysis, yet the quantification of these non-monetary and non-commensurable attributes has not always been possible. The idea of maximizing benefit minus cost, or minimizing cost, should be replaced by the notion of maximizing a host of (multiple) objectives, attributes, and criteria; yet the state-of-the-art has not been sufficiently advanced to make such quantification and analyses feasible. Research should be focused on such topics as:

--The quantification of such aspects as the irreversibilities (desertification) associated with policy-, planning-, and management-decisions related to arid and semiarid lands; the sensitivity, stability, and responsibility of dry lands to decisions on climatic, atmospheric, environmental, agronomic, socio-economic, and behavioral aspects; as well as other attributes such as esthetics, historical sights, social well-being from local, regional and national perspectives; the social costs and benefits of migration from the "Frostbelt" to the "Sunbelt" regions, and others.

--The development of decisionmaking methods and approaches for displaying, identifying, quantifying, measuring, evaluating and integrating non-commensurable objectives and attributes associated with both the social and environmental (non-market values), and economic considerations. In other words, social and environmental objectives should be considered on a par with economic objectives.

Research results which would assist in quantifying, articulating and thus realistically modeling, evaluating and analyzing arid and semiarid land issues and problems in a holistic approach should:

(a) Improve upon policy-, planning-, and management-decisions related to desertification prevention and arrest at the local, state, regional and national levels.

(b) Improve the quality, reliability, credibility, and the ultimate usability of mathematical models in policy-, planning-, and management-decisions related to arid and semiarid lands.

(c) Reduce the present gap between modelers, systems analysts, and the scientific community in general, on the one hand, and the decision-makers, practitioners, and model users on the other.

Risk and Impacts Analysis

The impacts of usage, planning, management, and policy decisions on arid and semiarid lands that could lead to desertification may be classified as either primary or secondary. Primary impacts are the expected risk (of any kind) or the intended results of these decisions. Secondary impacts are side-effects, unaccounted-for risk, or unintended results. Both types of impacts may have uncertainties associated with them.

Risk assessment is particularly desirable for arid and semiarid regions because of the recurring impact of natural events such as protracted and short-term droughts, destructive wind and hail storms, early and late frosts, and the impacts of human interevention together with marketing uncertainties. All costs and benefits of risk-taking at different levels of decisionmaking (federal, state, local, elected or appointed officials, etc.) need to be determined and defined.

Economic models, such as input-output models, need to be refined and updated periodically. Little attention has been given to the problem of lessening the impacts of a major decline of irrigated agriculture, for example, or providing alternatives which might preserve the economy of a region which has reverted to dryland farming. If changes or shifts in the production of goods and services are to be required, a slow but evenly paced transition would not disrupt the economy as severely as would a sudden change. In addition to economic factors, the social, institutional, legal and technological aspects should also be considered. The same is true if actions are necessary to maintain certain ongoing activities.

The research of the social-behavioral aspects in risk-benefit analysis should include an assessment of how people evaluate the potential return on and vulnerability of their investments, as well as how they perceive their options. The question of what motivates successful local participation in development and anti-desertification efforts should also be addressed. A better understanding of how people perceive their risks in arid lands would assuredly contribute to the development of more sensitive policy.

Environmental impact assessment requires a physical understanding of the arid and semiarid biomes and the risk of desertification, together with an analytical modeling capability which will display the feedback loops of the climate-soil-plant-animal system.

The work should begin with simple, macroscale (i.e., regional) representations of normal and stressed systems which follow a single critical flux (perhaps water in this case) and which take into account the substantial, natural uncertainties present in arid climates.

It is essential that programs of data acquisition and analyses be barried out in parallel with the modeling efforts, and that these guide and correct each other continuously.

Research is needed to determine:

--The quantification of risk so that it can be included in the quantitative evaluation and analysis, along with all other benefits and costs.

--The distributional effects of certain policies related to soil, water and other resources conservation.

--How to reduce the socio-economic risk, as well as other risks, associated with the consequences of policy-, planning-, and management-decisions related to arid and semiarid lands and desertification.

--Economic allocations of water and vegetation, the socio-political impacts from reallocation of these resources supplies, and the role of arid and semiarid lands in the national economy.

--Traditional methods of coping with the inherent variability of arid lands, including strategies for dealing with risk. Findings should inform us of current policy and enable better prediction of the consequences of altering or eliminationg traditional methods of coping with aridity and desertification.

--Aspects of the decisionmaking process by/all groups including user groups, public interest lobbies and environmental groups: examining their respective representativeness and membership.

--The legislative objectives of specific programs relating to the use of resources in an arid environment as given, and the institutional factors that prevent the achievement of these programs.

--Relation of natural and manmade hazards in arid zones - and of our increasingly greater capacity to predict these hazards - to the obligations of local state institutions to mitigate these hazards (especially the question of tort liability of governmental institutions).

Methodologies for Planning and Managing Arid Areas to Prevent and Arrest Desertification

Studies leading toward integration of the resource base quality, supply, demand, planning, and management at all governmental levels are needed. Such integrated resources planning, management, and regulating functions must then become an integral component of the broader function of land use planning and management. Many resources' planning and management, for example water, is largely a state function, often differing from federal agencies' functions. In water quality planning and management (pollution control), there are overlapping federal and state functions as well as local government functions. Local governments may have limited roles in water quantity and other resources management. State and federal government have limited voices, if any, in land-use planning and management.

A greater effort should be made toward contingency planning. Models should be created for various scenarios, such as:

--Providing all requirements for people at any place (e.g., moving water to the people).

--Restricting population to places where these requirements can be met (moving people to the water).

--Leaving developments to themselves.

--Formulating management policies, such as: Regulating certain types of recreation; Limiting resources transfers; Limiting or stopping agricultural subsidies; etc.

--Establishing contingency plans for dry years and gaining a better understanding of resiliency, by examining social and behavioral methods of adjusting to shortage, and to natural and historical adaptation mechanisms.

Other suggested research topics are:

--Examine the manner in which the configuration of existing political jurisdictions affect the design of policies appropriate to the characteristics of arid lands. Among the questions that should be addressed are:

- The implications of developing and exporting resources of arid lands for utilization outside arid regions.
- The costs and benefits of applying national environmental standards to arid lands.

--Examine existing and alternative mechanisms for evaluating the appropriateness of technology used in arid lands development. The criteria for assessing appropriateness should include effectiveness in matching project scale with both local needs and local resources, to ensure a project's long-term operation.

--Analyze individual and group perception of desertification and resources problems, and the relation of these perceptions to the manner in which resource programs are conduted.

The relationship among the policy analysis, research and societal demands requires feedback to determine feasibility of policy. Studies should be conducted to improve the implementation of all policies, including:

--Identifying incentives and institutional actions for conservation in drought years, and in controlling desertification.
--Identifying and triggering social change and institutional action to conserve or increase the resilience of the arid/semiarid systems.

This section was adopted from the following sources:

Berry and Ford, 1977
Caulfield, 1978
Cochran and Fordham, 1978
Dirmhirn, 1978
Epstein, 1978
Fogel and Harwood, 1978
Fowler, et al., 1978
Goodin and Northington, 1979
Haimes, 1979
Ingram, et al., no date
NAS, 1975
NAS, 1979
NRC, 1976
Rosenberg, 1979
Sabadell, 1979
Steele, 1978
Sweazy, et al., 1978
White, 1960
Yevjevich, et al., 1977

IX. International Activities

It has long been understood that desertification processes have a global dimension on both the physical and political levels.

The arid belts around the world are a reflection of widespread weather patterns determined in turn by such factors as upper air winds and ocean currents. Shifting patterns directly affect the availability of moisture. The present geologic epoch, the Quaternary, has seen long-term landscape changes effected by a variety of global, tectonic, erosional and seismic activities.

Improved communications have led to greater world awareness of droughts and subsequent famines in remote parts of the globe. Greater research has led to a more general understanding of the problem. According to Professor J. A. Mabbutt, an Australian geographer specializing in arid lands, desertification is a human problem, not only in its consequences but also in its causes. In searching for causes beyond basic growth of population and pressures on natural resources, it has been recognized that such activities as tree-cutting and herding have conspicuously modified the character of the land in regions such as the Mediterranean Basin and the Sahara. Large-scale irrigation works also have had long-term adverse effects, such as abandonment of land no longer fertile.

The more industrialized nations of the world are seen to be causing the greatest perturbations in the environment. Acid rain, for example, results from products of combustion which may fall thousands of miles from the source. Both freon gas releases, affecting the vital ozone levels in the stratosphere, and the buildup of CO_2 resulting from fuel combustion may, if unchecked, have disastrous effects on the world's climate. It can be seen that while desertification processes are most visibly set in motion by local actions, conditions may also be affected by gradual changes occasioned by distant environmental manipulations.

A growing responsibility is recognized for conducting international studies of the problem and of arriving at mitigating actions, cooperatively. Additionally, technologies for combating the effects of desertification are frequently transferable and pilot studies can be most productive when based on the widest possible experience and knowledge. In recognition of multinational involvement, the United States has taken an active role in U.N. and other forums, through its AID programs, and in negotiations with Mexico on the shared boundary problems, in attempting to understand and solve potential threats to the environment. American scientists have been prominent in a succession of international science and technology-related endeavors organized by groups such as the International Council of Scientific Unions (ICSU). The subject of desertification has had specific attention by the U.N. since the conference convened in Nairobi, Kenya, in 1977.

Desertification and the United Nations

Current international concern with desertification followed the disastrous drought that struck the southern borders of the Sahara between 1968 and 1974. This Sahelian drought led to widespread destruction of pastures and mass death of livestock in pastoral communities, and to repeated crop failure in the agricultural lands to the south. Climatically and ecologically, it was as if the Sahara desert had extended its limit southward by 5 degrees of latitude. By 1972 the livelihood systems over large areas were in a state of virtual collapse, famine was widespread, and wholesale out-migration of refugees was taking place. It is estimated that 250,000 people died as a result of the drought, and that the loss of life would have been even larger but for the massive international relief operation that was belatedly mounted.

At the time of the tragedy in West Africa there was also severe drought and famine in the Sudan and Somalia further east, and in the Indian deserts where monsoon rains were generally below average throughout the 1960s. Following a number of resolutions by concerned international bodies, the General Assembly of the United Nations agreed in December 1974 to initiate concerted international action to combat the spread of desert conditions. Resolution 3337 (XIX) called for an international conference to be held in 1977 to give impetus to such action, specified that a world map should be prepared to show the extent and intensity of the problem, asked that all available information on desertification and its consequences for development should be gathered and assessed, and called for the drawing up of an international plan of action to combat desertification.

Fundamental national differences are recognized in the Plan of Action to Combat Desertification adopted by the United Nations. Although there is a call for international collaboration at all levels, the plan recognizes that action will primarily be within national plans, responsive to local values and objectives, and ultimately dependent on the provision of appropriate technology at the national scale.

To assist the United Nations Conference, case studies of desertification were commissioned from among developing arid countries to demonstrate the nature of the problem, and further studies (with greater emphasis on the success of combative measures) were presented by the governments of technologically more advanced nations. The case studies were invaluable in demonstrating the importance of social, economic and demographic factors as determinants of the patterns and nature of desertification, particularly through their influence on land use.

On the world scene, desertification in dry-farming systems has commonly followed the extension of cultivation into areas of unduly high drought

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risk and on unsuitable terrain and erodible soils. Among the subsistence economies, as in many Middle Eastern countries and in India, this expansion is associated with pressure of increasing population and a growing need for production of food crops, with mounting land hunger. The expansion of cultivated area tends to accelerate during runs of good rainfall seasons and has everywhere been facilitated by the increasing mechanization of agriculture.

In the face of growing food demands, there has been a widespread tendency toward the replacement of rangelands by cultivated fields, particularly where labor is abundant and cheap. The promise of a greater food return is at the cost of stability, for whereas in years of drought animal-based systems can continue to provide some subsistence, crop failure can be complete. Further, a cover of natural pasture provides a check against accelerated soil erosion where cultivated lands are left vulnerable.

The main physical problems associated with desertification in irrigated regions are waterlogging and salinity. Salt-affected and waterlogged soils occur in 50% of the irrigated area in Iraq, 23% in Pakistan overall, 80% in the Punjab, 30% in Egypt, and 15% in Iran. According to FAO estimates not less than 50% of the world's irrigated land is already saline, and every year several hundred thousand hectares of land are lost in consequence - probably equivalent to the area of new lands being brought under irrigation annually.

Increasing salinity of river flows has caused great concern, specially where more than one state is directly involved. An example of the problem created by salinization along international rivers is the case of the U.S. and Mexico, concerning the use and quality of the waters of the lower Colorado River.

The UN studies also record successes in establishing stable and productive systems of land use in arid and semiarid lands. There are examples of progress toward a more realistic appreciation of the true productivity of rangelands in terms of safe carrying capacity, and of what constitutes a minimum holding for economic operation.

The United Nations' proposed Plan of Action to Combat Desertification stresses throughout the need for community awareness, support, and participation in national programs. General public attitudes are important and there is a widening appreciation of the limitations and assets of arid and semiarid zones, for instance, an appreciation of the hazards of drought for the land user, of limits to production set by scanty rainfall, and of the sensitivity of desert ecosystems under pressure of human land use and misapplied technology carried in from other zones. There is wider acknowledgement that, despite their vastness, the resources of the drylands are not inexhaustible, and that conservational attitudes are as necessary here as in the better-watered parts of the continents, perhaps even more so given the drastic repercussions of misuse of these extreme environments.

Increasingly, desert lands are becoming valued for purposes other than immediate profit. Recognition of the importance of native plants and animals in desert refuge areas as a unique national and world heritage, and perhaps as a gene pool for future selection, is now expressed in the establishment of nature reserves. The growing use of the deserts for tourism and recreation reflects an appreciative response to the great scenic beauty and natural interest of their landscapes, and to the restorative impact of the immense desert expanses on urban people.

Professor Mabbutt points out that viewpoints that have influenced expectations about the future of the dry zones must bear some responsibility for their present status. One is the temptation to see the dry sparselands of the world as untapped resources; another is the tendency to accept the selective memory of good seasons in these regions as grounds for a predicted development; and a third is an uncritical trust in technology development and transfer as a means of overcoming environmental constraints and of increasing productivity, often on the evidence of results achieved in quite different physical and socioeconomic settings.

The first of these assumptions contributed to the launching of UNESCO's Arid Zone Programme in 1951. The simplistic arithmetic, that the arid and semiarid lands comprised about a third of the earth's surface but supported less than one-eighth of its population, was accepted as evidence of an underdevelopment that could not be tolerated in a world faced with overcrowding and with shortages of food and fibers.

During the next eleven years, reviews were commissioned and symposia convened on many major environmental problems of the arid and semiarid zones. The twenty-eight volumes published under the Programme comprise an imposing body of fundamental and applied knowledge of the world's dry environments. In addition, a large number of training centers were established, some 200 research units were set up in 40 countries, and several thematic maps were prepared to depict current scientific knowledge concerning the natural resources of the arid zones.

The Sahelian drought of 1968-73, which followed closely after the compilation done by UNESCO, triggered the 1974 resolution calling for a conference on desertification. This fact recognized that special attention and thorough analyses were necessary to understand and deal with the ecological and social changes brought about by the exploitive uses of some of the arid lands resources.

Since the Nairobi Conference the desertification control activities under the UN framework have proliferated. An international consultative group on desertification was formed. In response to resolutions and decisions, as well as the recommendations of the Consultative Group, the Executive Director of the UN Environmental Program (UNEP) invited governments and international organizations to declare their interest in membership or co-sponsorship of the Consultative Group. To date, he has received such declarations from many governments, including the U.S.

Co-sponsoring international organizations are: Food and Agriculture Organization of the UN; International Fund for Agriculture Development; UN Development Program; UN Educational, Scientific and Cultural Organization; UN Environmental Program; UN Fund for Population Activities; UN Industrial Development Organization; World Food Council; and World Meteorological Organization.

The Desertification Unit established in 1978, within UNEP, in response to the General Assembly, assists the Executive Director and the Governing Council of UNEP in global coordination and followup implementation actions. In addition to this main function, the Desertification Unit serves as the secretariat to the Consultative Group and to the Inter-Agency Working Group on Desertification (IAWGD). Furthermore, in order to avoid duplication of activities within UNEP, all activities related to arid and semiarid lands ecosystems and to combating desertification are coordinated by the Desertification Unit. The Desertification Unit cooperates fully in all activities related to arid lands and combating desertification which are being carried out by the various units within the Program, such as the Global Environmental Monitoring Systems (GEMS). At the United Nations level, the coordination is provided through IAWGD. The Desertification Unit, in conformity with the overall UNEP mandate, is also responsible for the catalysis of activities related to its area of concern. The Unit works very closely with the UN Sahelian Office and other regional entities. By resolutions of May and June 1978, the institutional support for the program became a shared responsibility of the UNEP and the UN Development Program (UNDP).

The development of an international program to maintain the ecosystems of arid and semiarid lands and to combat desertification has been a high priority of the U.S. since the UN Conference on the Control of Desertification (UNCOD). Since then the U.S. has worked in a number of multilateral and bilateral forums to implement Conference recommendations. In particular the arid lands program with Mexico is seen as an important symbol and manifestation of commitment to an international program, and also of the importance attached to arid lands management in the U.S. relationships with Mexico. The U.S. position is that intensification of national efforts to implement cooperative planning is necessary. It should be noted that during Fiscal Year 1980, AID will obligate more than $36 million for desertification control projects. An even greater anti-desertification effort is anticipated by AID during FY 81 and 82 as a result of planning now underway for bilateral projects.

Specific U.S. commitment and support since the 1977 UN Conference includes:

(a) establishment of a broad-based interagency committee to plan and monitor our national desertification efforts and to prepare a National Plan of Action to Combat Desertification which will probably be available in 1981. The project has recently been retitled the Desertification Assessment for the United States.

(b) the U.S.-Mexico Agreement on Arid Lands Management and Desertification Control, signed in February 1979 by Secretary Vance, to sets up a joint work program to combat desertification in the border zone.

(c) U.S. membership in the Consultative Group for Desertification Control set up by UNEP to assess proposed desertification control projects.

(d) expansion of our bilateral development assistance program in areas related to desertification, including energy alternatives to firewood; support for the Sahel Development Program; reforestation and remote sensing applications in arid lands; and desertification monitoring and assessment.

(e) expansion of U.S. research in areas such as salt- and drought-tolerant plants, commercial development of various arid lands plants, and new technologies and management techniques for watersheds and rangelands.

The U.S.-Mexico Agreement on Arid Lands Management and Desertification Control includes cooperative research, demonstration, and application projects in the following areas: new crops, soil conservation, rangeland management, livestock production and conventional crops, forestry, equipment research and development for agricultural production and revegetation, water harvesting techniques, and watershed management.

The U.S. and Mexico are also cooperating in the development of their respective National Plans. During a March 1980 consultation in Lubbock, Texas, both sides agreed to exchange draft Plans for the purpose of reviewing them for possible integration of sections dealing with the border zone. In addition, it was agreed to launch a cooperative research program on desertification monitoring, moving toward a goal of an operational regional program. A fourth bilateral meeting on desertification will be held in Mexico City in February-March 1981, prior to the 9th UNEP Governing Council meeting, in order to analyze progress in the elaboration of the Plans, and to review and attempt to formulate common positions on issues which will come before the next Governing Council. Future workshops under the aegis of the U.S.-Mexico Working Group on New Crops, Arid Lands and Agricultural Productivity will focus on Water Harvesting (1980), Range Management (1981) and Watershed Management (1982).

Desertification is recognized as a global problem, differing in its aspects from region to region, but amenable to study and action based on cooperative research and programs among governments. The United States has recognized the importance of this topic both domestically and at the international level by confronting the problem through a variety of mechanisms on different fronts and with full realization of the mutual dependence the countries of the world share in attempting to improve international land quality and to prevent the human tragedy that will result from further desertification.

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APPENDICES

Appendix A: Geographical Regions

The 17 Western and Great Plains States have been divided into eight regions roughly the same as those in Morris E. Austin's Land Resource Regions and Major Land Resource Areas of the United States. These regions (Figure A-1) overlap with the Great Plains, Mountain, and Pacific regional divisions (Figure III-1) and also with the ecoregions (Figure E-1); however, the overlaps are not exact. The location, topography and elevation, climate, geology, water, and population centers of each region are described here to give a general understanding of their diversity.

a. Northwest Rangeland

Location: This region runs north-south along the eastern edge of the Cascade Mountains with extending arms along the Columbia and Snake Rivers.

Topography and Elevation: This is an area of varied topography including mountain foothills, basins, plains, and plateaus. The elevation ranges from 1,000 feet on the plains, to about 4,500 feet on the plateaus, to 10,000 feet at the crests of some mountains.

Climate: The average annual precipitation is less than 20 inches, with an extreme low of 6 inches. Winter rainfall is greater than summer rainfall. Average annual temperatures range from 40°to 55°F. Average freeze-free periods range from 50 to 200 days.

Geology: The geology of this region is primarily volcanic rocks of Quaternary and Tertiary age. Soils vary widely, but the alluvials are frequently the most productive.

Water: Water from the Columbia and Snake Rivers irrigates agricultural areas.

Population Centers: Spokane, Washington (309,000 pop.) and Boise, Idaho (114,033) are the population centers of the region.

b. California Subtropical

Location: This region lies within the State of California, covering the coastal plain and central valley regions west of the Sierra Nevada and the Southern California mountains.

Topography and Elevation: The coastal plain and central valley both range from sea level to 2,000 feet in elevation.

Climate: Average annual precipitation is from 5 to 25 inches withvery dry summers. Freeze-free periods may be year-long in the southern portion of the region and near the coast, and are generally 250 days long elsewhere. Average annual temperatures are from 55° to 65°F.

Geology: The valleys are alluvium filled; the coastal plain is geologically composed of granitic outcrops and marine depositional material.

Water: The Sacramento and San Joaquin Valleys are heavily irrigated from the Sacramento and San Joaquin Rivers and from groundwater sources.

Population Centers: A favorable climate and heavy industrialization has led to a high density population, and urbanization continues to expand rapidly, often crowding out agriculturally productive land. Population centers are Sacramento (90,000), San Francisco (3,158,000), Fresno (464,000), Los Angeles (6,997,000), and San Diego (1,624,000), each with a large suburban area.

c. Western Plains and Plateau Rangeland

Location: This is the largest of the regions, extending from south and west of the Cascades and Rockies, south to the Mexican border, and east into the Trans-Pecos area of Texas. Much of this area is public land.

Topography and Elevation: The region is a basin and range type of topography with plateaus varying in elevation from about 4,500 to 7,500 feet, and basins as low as 250 feet below sea level in the Imperial Valley. There are a few small mountain ranges with peaks as high as 13,000 feet. The lower Colorado River valley provides the only large extent of low-lying land.

Climate: The average annual precipitation is generally less than 10 inches on the plains, but may be as high as 40 to 50 inches in the mountains. Precipitation is higher in the summer in the southeastern portion of the region. Elsewhere, rainfall tends to be higher in winter. Average annual temperatures are 45° to 55°F, ranging from 35° in the north to 70° in the south. Freeze-free periods range from less than 90 days in the north to more than 240 days in the south.

Geology: The region has a great variety of geologic formations. The geologic origin ranges from volcanic to terrestrial and marine depositions, and the ages of the rock extend back to the Precambrian Age. The Colorado Plateau at the Four Corners area (common border point of Arizona, New Mexico, Colorado, and Utah) where the Grand Canyon cuts through and reveals the many layers of sedimentary rock is the outstanding geologic feature.

Water: All principal rivers in this region have their headwaters in the mountainous area, flowing into and through dry areas. They are the Colorado, the Humboldt and the Rio Grande.

Population Centers: The region is sparsely populated but has urban centers at Salt Lake City, Utah (800,000); Las Vegas, Nevada (346,000); Phoenix (1,224,000) and Tucson (451,000), Arizona; Albuquerque, New Mexico (393,000); and El Paso, Texas (431,000).

d. Rocky Mountain Rangeland

Location: The Rocky Mountain chain extends into the U.S. from Canada and continues into New Mexico.

Topography and Elevation: The variances of topography and elevation are extreme, with valleys down to 2,000 feet and peaks up to 14,500 feet. The meadows are at about 8,000 feet.

Climate: In many valleys, average annual precipitation is less than 10 inches; average annual temperatures are 40° to 50°F. The longest freeze-free period is 120 days. The mountains receive more rain and snowfall, especially in the winter, but have lower average temperatures and a considerably shorter freeze-free period.

Geology: The region is heavily folded and faulted volcanic, sedimentary, and metamorphic rock. Alluvial soils are predominant in the valleys.

Water: Perennial streams fed by mountain rainfall and melting snow provide some of the area with sufficient water. The valleys and meadows of this region are prone to desertification processes because of slope drainage and water supply problems. This is especially true in the San Luis Valley of Colorado. Salinity problems result from heavy irrigation.

Population Centers: The ruggedness of the terrain has forced settlement into the valleys, where the most agriculturally productive lands are, creating an increasing conflict between the needs of urbanization and agriculture for both land and water. The area is sparsely populated, with the largest population and industrial center at Denver, Colo. (1,438,000), and with other smaller populations centers spread along the Front Range.

e. Northern Great Plains

Location: This region extends along the Canadian border, encompasses the northern portion of Montana and the entire State of North Dakota, and extends though the central portion of South Dakota.

Topography and Elevation: The region is comprised of smooth, rolling plains on which spring wheat thrives if enough moisture is available. Elevations range from 1,000 to 4,000 feet.

Climate: Average annual precipitation ranges from 10 to 24 inches and most of it occurs during the growing season. Average annual temperatures are 40° to 45°F. The freeze-free season ranges from 100 to 145 days.

Geology: Like most of the Great Plains area, the region is underlain by Precambrian basement rock and covered by sedimentary rock. Rich fertile soils are predominant.

Water: The Missouri River system flows through this region, but most of the agriculture is dryland farming with irrigation from the river only in floodplain and adjacent areas.

Population Centers: The population density of the region is low. Bismarck (42,113), Grand Forks (42,052), and Fargo (58,256), North Dakota; and Pierre (12,110), South Dakota, are the main urban centers.

f. Western Great Plains Rangeland

Location: This region has a north-south alignment and stretches from western Montana through western Wyoming, eastern South Dakota, into north central Nebraska along the Platte River, eastern Colorado, and east-central New Mexico. It is comprised of the high plains and foothill regions just east of the Rocky Mountains.

Topography and Elevation: Elevation on these dissected plains and foothills ranges from 2,000 to 7,000 feet, with an average of 4,000 feet.

Climate: Average annual precipitation is 10 to 25 inches, and is spread over the months from mid-spring to autumn. Temperatures average 45°F, but are colder in the north and warmer in the south.

Geology: The region is Precambrian covered by sedimentary rock composition, as is most of the Great Plains. Reddish brown soils cover much of the region.

Water: The Platte River system flows through the region, but little is used for irrigation. Dryland farming is prevalent, as is rangeland grazing.

Population Centers: Rapid City, South Dakota (53,070); Casper, Wyoming (46,903), and Roswell, New Mexico (39,511) are the main urban sites.

g. Central Great Plains

Location: This region, extends from southern Nebraska through western and central Kansas, western Oklahoma, and the Texas panhandle and rolling plains areas. The land is used primarily for rangeland and winter wheat production.

Topography and Elevation: This is a region of hills and rolling plains, ranging from 1,000 to 5,000 in elevation.

Climate: 15 to 30 inches of precipitation fall on this region, mostly during the summer months. Average annual temperatures range from 50° to 65°F, and the freeze-free period ranges from 150 to 240 days.

Geology: The geology of the region is precambrian sedimentary rock. Soils typical of the prairies are prevalent.

Water: The Red and Arkansas Rivers flow through the region and provide irrigation water for adjacent land, but groundwater is the main supply for irrigation (Ogallala Aquifer). Center pivot systems are prevalent in the region.

Population Centers: The sparsely populated region has urban centers at Lincoln, Nebraska (166,311); Wichita, Kansas (391,000); Oklahoma City, Oklahoma (762,000); and Lubbock, Texas (200,000).

h. Southwest Plateau and Rangeland

Location: This small region lies within southwestern Texas.

Topography and Elevation: The plains and plateaus of this region range in elevation from sea level to 4,000 feet.

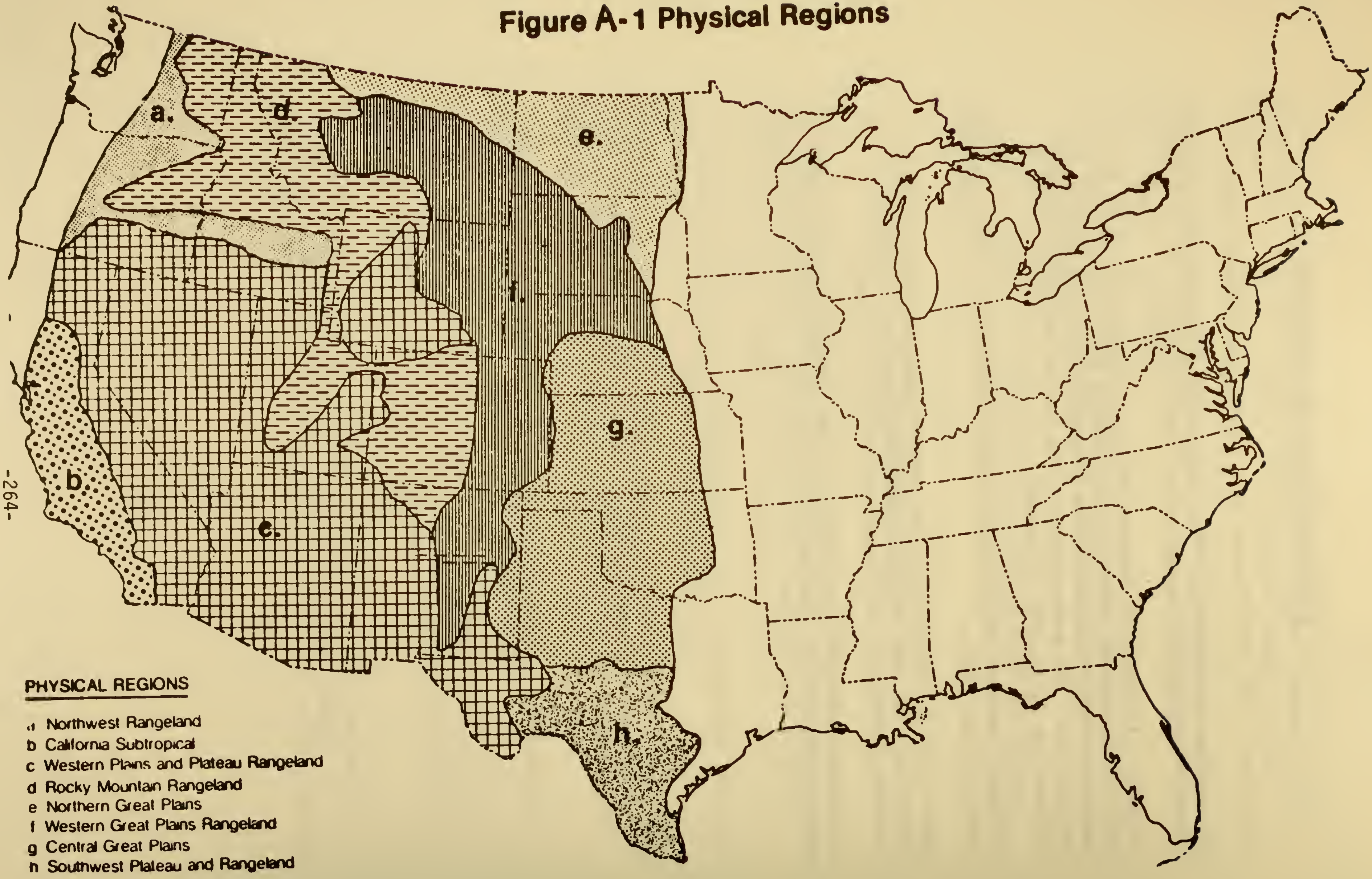
Climate: Although the average annual precipitation is 20 to 30 inches, the average annual temperature is high (60° to 70°F), making the effectiveness of the precipitation low due to high evaporation. The seasonality of the precipitation is divided between the spring and the autumn.

Geology: Sedimentary layers, primarily limestone, are found over Paleozoic Age rock.

Water: The Rio Grande provides some irrigation water within its floodplain, but the aquifers underlying much of the region provide groundwater for livestock and domestic needs.

Population Centers: San Antonio, Texas (996,000) is the main population center of the region.

Figure A-1 Physical Regions


a.
d
e.
f.
g.
b.
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PHYSICAL REGIONS
a Northwest Rangeland
b California Subtropical
c Western Plains and Plateau Rangeland
d Rocky Mountain Rangeland
e Northern Great Plains
f Western Great Plains Rangeland
g Central Great Plains
h Southwest Plateau and Rangeland

Appendix B. Climatological Conditions

Introduction

The main characteristic of arid and semiarid lands is the scarcity of precipitation or moisture, a condition which is directly affected by other elements of the climate, such as temperature, sunshine, wind and moisture conditions, and their extremes. See figures B-1 & B-2. Two climatological extremes common to the study area--drought and flash floods-are explained briefly in this appendix.

The appendix also briefly examines the effects of albedo and climate change and their known and potential impact on desertification.

a. Drought

Drought is an important climatological feature of arid and semiarid lands because it may trigger or intensify desertification, as well as have an economic effect on the local and regional residents. Drought is a normal temporary feature of the climate of arid and semiarid lands which occurs in varying patterns and frequency throughout the U.S.

There exist many definitions of drought, but the main characteristic is that during periods of drought, areas receive only a fraction of their average annual precipitation. The length of the drought can range from a few months to several years.

It is important to distinguish between aridity and drought. Aridity is a permanent climatic condition of low average precipitation. Drought is a temporary phenomenon in which precipitation is significantly lower than average (Rosenberg 1978).

Droughts involve great uncertainty in terms of where and when they will occur, duration, severity, and extent of impacts. Drought severity is measured in terms of:

--Actual precipitation in comparison to the average annual precipitation;

--Length of drought;

--Season of drought;

--frequency of drought (Heath 1978).

Because we cannot as yet predict the occurrence or the severity of drought, it is necessary to have alternative resources management plans prepared for drought occurrences so as to ameliorate their short-and long-term impacts (WESTPO 1978). See figure B-3.

b. Flash Floods

Flash floods are produced by highly localized and abundant rainfall caused by occasional slow-moving weather fronts; orographic lifting and thus cooling of warm, moist air; and "Mexican hurricanes" or tropical low pressure centers which move from the Pacific onshore in Mexico and then northerly, or northeasterly into the arid and semiarid regions of the U.S. Flash floods also occur due to physiographic conditions such as watershed relief, drainage, geology, topography, the existing vegetation, and hydrologic conditions.

Rainfalls of 3 1/2 inches in 1 hour are not unusual in the Western States. (Renard 1970). There are reports of 1.17 inches in 3 minutes (Bigger 1959), and even of 7 inches in 30 minutes (Hoyt 1955). While the more intense rainfall usually comes at the beginning of the storm, it may be followed by an hour or more of less intense rainfall, producing a great deal of runoff. In one flash flood in Arizona, streams rose 5 to 10 feet per hour, and one creek crested at 36 feet over the normal level (NOAA 1971).

Flash floods do considerable damage to property, soil, plants, animals, and people. Severe erosion, silt, and sediment in waterways are the immediate manifestations of flash floods, but the loss of flora, fauna, and nutrients is of great import as well.

c. Albedo

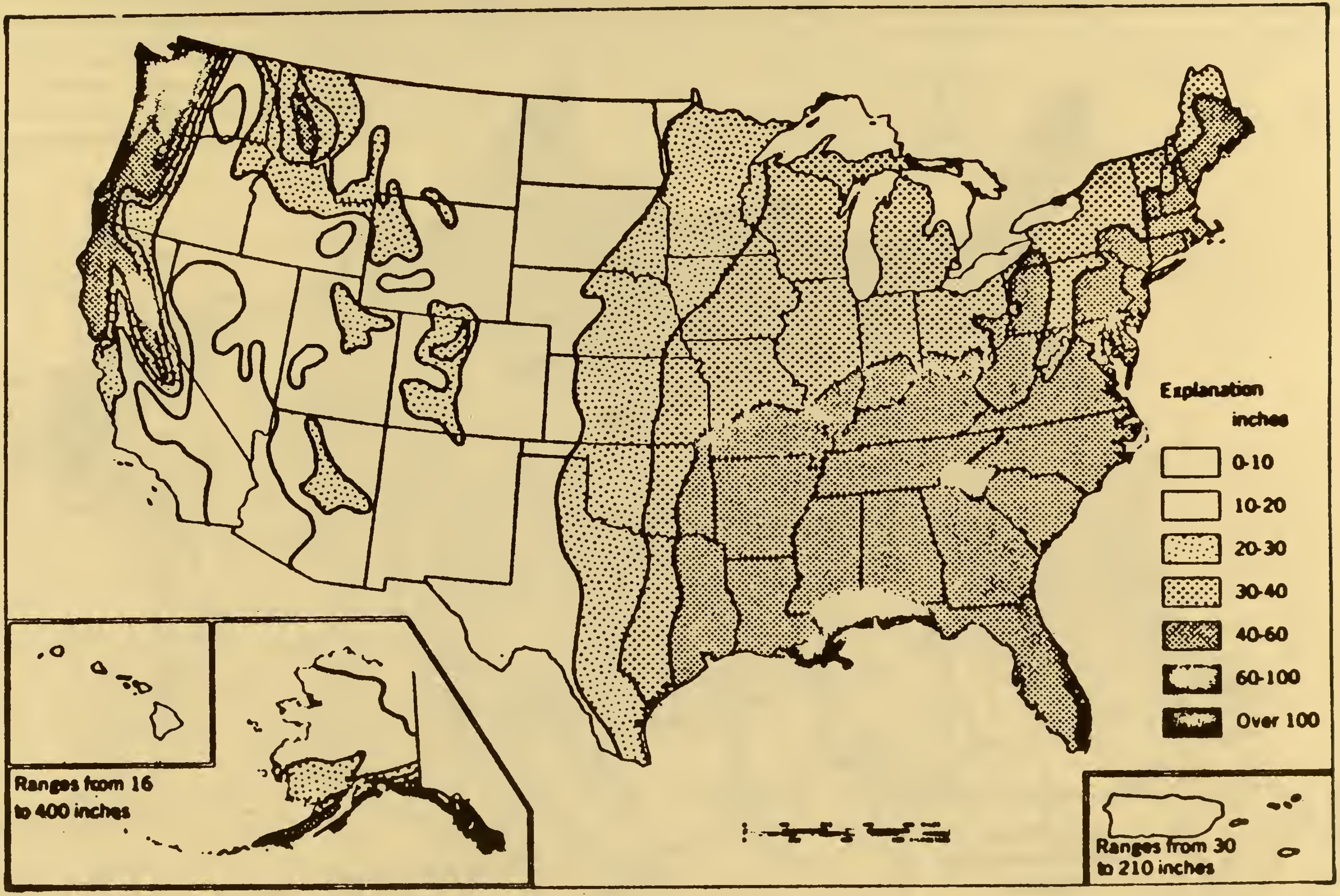
Albedo is the portion of incoming solar radiation which is reflected back into the atmosphere. Light-colored objects (e.g., clouds) reflect back more radiation and thus have more albedo. Because the arid areas have characteristically clear skies, they have a low atmospheric albedo. Much of the incoming solar radiation is absorbed by the land which, in turn, raises the surface and soil temperatures.

The amount and distribution of the vegetation covering the soil affects the albedo of the land. Dry, bare lands have a higher surface albedo than do humid, densely vegetated lands because more solar radiation reaches, and is reflected by the ground. An increase in surface albedo unfavorably alters the water budget and runoff, allowing the soil to be further degraded, with desertification as a result. Surface albedo is increased by activities such as: overgrazing, indiscriminate use of fire, deforestation for slash-and-burn agriculture or for fuel and timber; and salinization of soils. This occurs partly because of the destruction of vegetation, and partly because of the creation of salt flats with very high albedo rates (Sagan, 1979). The variation of climate is a long-term process caused by natural conditions, such as the changes which occured during the ice ages. The changes are over such a long stretch of time that there is little control or concern over them. Variability of climate, however, is a normal short-term phenomenon common to all climates, but more pronounced in dry climates, which both concerns and can be impacted by human actions. For example, the burning of fossil fuels and the changes in natural vegetation have led to steadily increasing atmospheric concentrations of carbon dioxide (CO2).

Recent studies have shown that the continuation of this trend will lead to double the amount of CO2 in the atmosphere by the first half of the 21st century. This condition could result in the warming of the earth's surface between 2°C and 3.5°C, with greater increases at higher latitudes. The uncertainty of the estimate is due to the imperfect ability to predict the future behavior of both human and biospheric activity (NAS 1979).

The increase in temperatures could have stong impacts on climate, due to shifts in the distribution of climatic regimes. (It is probable that the impact of climate change could be delayed by the capacity of the deeper oceans to absorb heat, but when that equilibrium is reached, the warming will occur (NAS 1979).) Any changes in climate will have many impacts along a chain of reaction, from direct crop impacts to the effects on farm or pastoral management, the external markets, and on the supplies of energy, fertilizer, and fisheries (Hare 1980).

Figure B-1



Average annual precipitation. (U.S. Water Resources Council, 1978e)

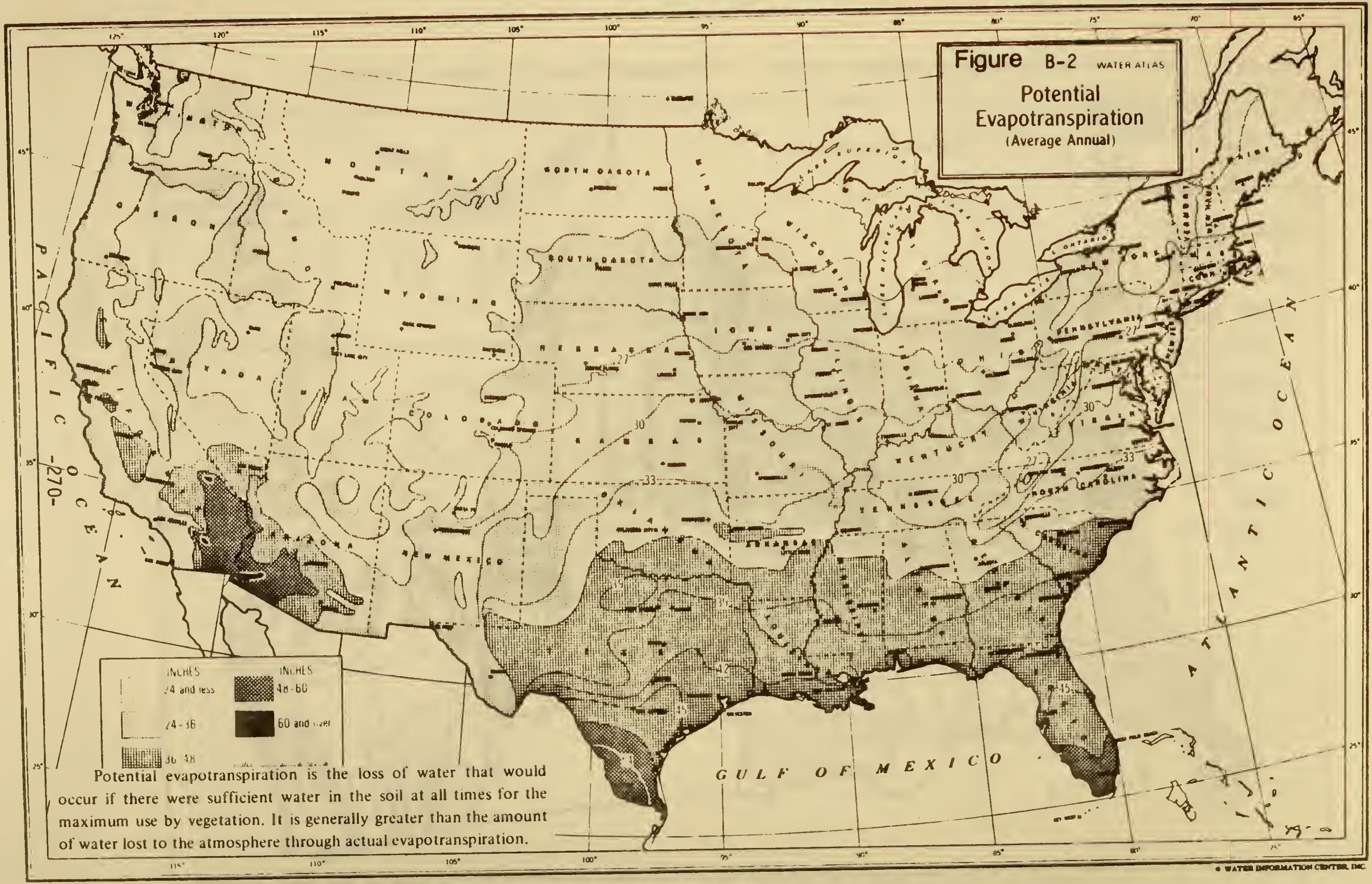


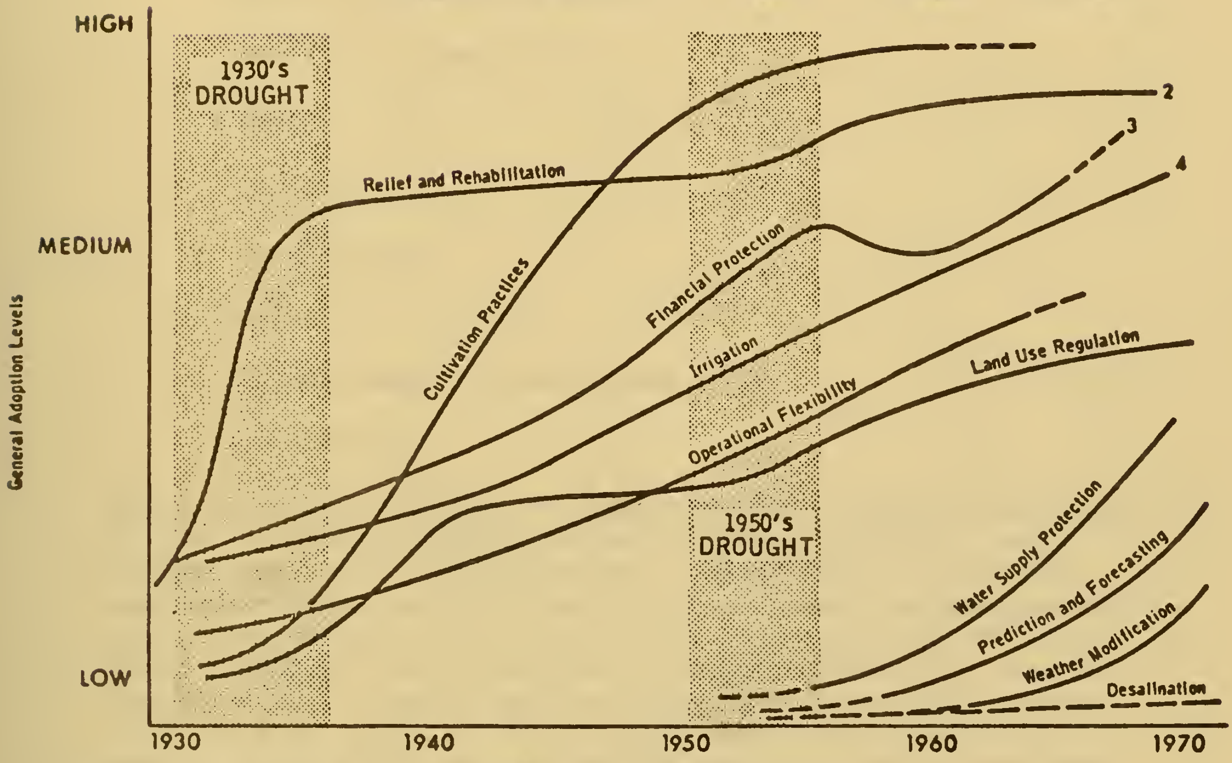
Figure B-2 Potential Evapotranspiration (Average Annual)

Potential evapotranspiration is the loss of water that would occur if there were sufficient water in the soil at all times for the maximum use by vegetation. It is generally greater than the amount of water lost to the atmosphere through actual evapotranspiration.

Source: James L. Geraghty, et al., Water Atlas of the U.S., Port Washington, N.Y.: Water Information Center Publication, 1973.

Figure B-3

Generalized Historical Trends of Drought Adjustment



1. Very rough approximation of relative levels of adoption
2. Institutional arrangements for R&R -- not payments
3. Shape of curve generalized from number of acres insured and amounts of loans in the United States (dip in 1950's reflects lower adoption of insurance at that time)
4. Based on total irrigated acres in the United States

Source: Norman J. Rosenberg, ed., North American Droughts, Boulder, Colorado: AAAS, 1978.

Appendix C: Soil

The soils of arid and semiarid lands have characteristics which make them prone to erosion, waterlogging, and/or salinization. These characteristics are discussed in this section.

Soil is the mineral and biologically active portion of the earth's surface which supports vegetative growth. Some of the characteristics that determine the types of soils are:

- content of sand and clay
- acidity or alkalinity
- depth
- porosity
- permeability
- color
- organic matter content; and
- temperature.

Soils of the arid regions of the United States belong principally to the Aridisol, Mollisol, Entisol, Alfisol, Vertisol, and Ultisol soil orders (Dregne 1976). Upland soils are usually medium-to-coarse textured; soils of topographic depressions and along the coastal plains of Texas are fine-textured; and soils found on river flood plains are of variable textures. Most of the soils have slightly acid to alkaline reaction (ph) and are calcareous at depths of less than 6 feet (2 meters). Organic matter contents are low, and soil structure is weakly developed.

The USGS National Atlas of 1970 defines the cited orders of soil as follows:

Alfisols: soils with gray to brown surface horizon, medium to high base supply, and subsurface horizons of clay accumulation.

Aridisols: soils with pedogenic horizons, low in organic matter, usually dry.

Entisols: soils with nearly black, organic-rich surface horizon and high base supply.

Ultisols: soils with horizons of clay accumulation and low base supply.

Vertisols: cracking clay soils.

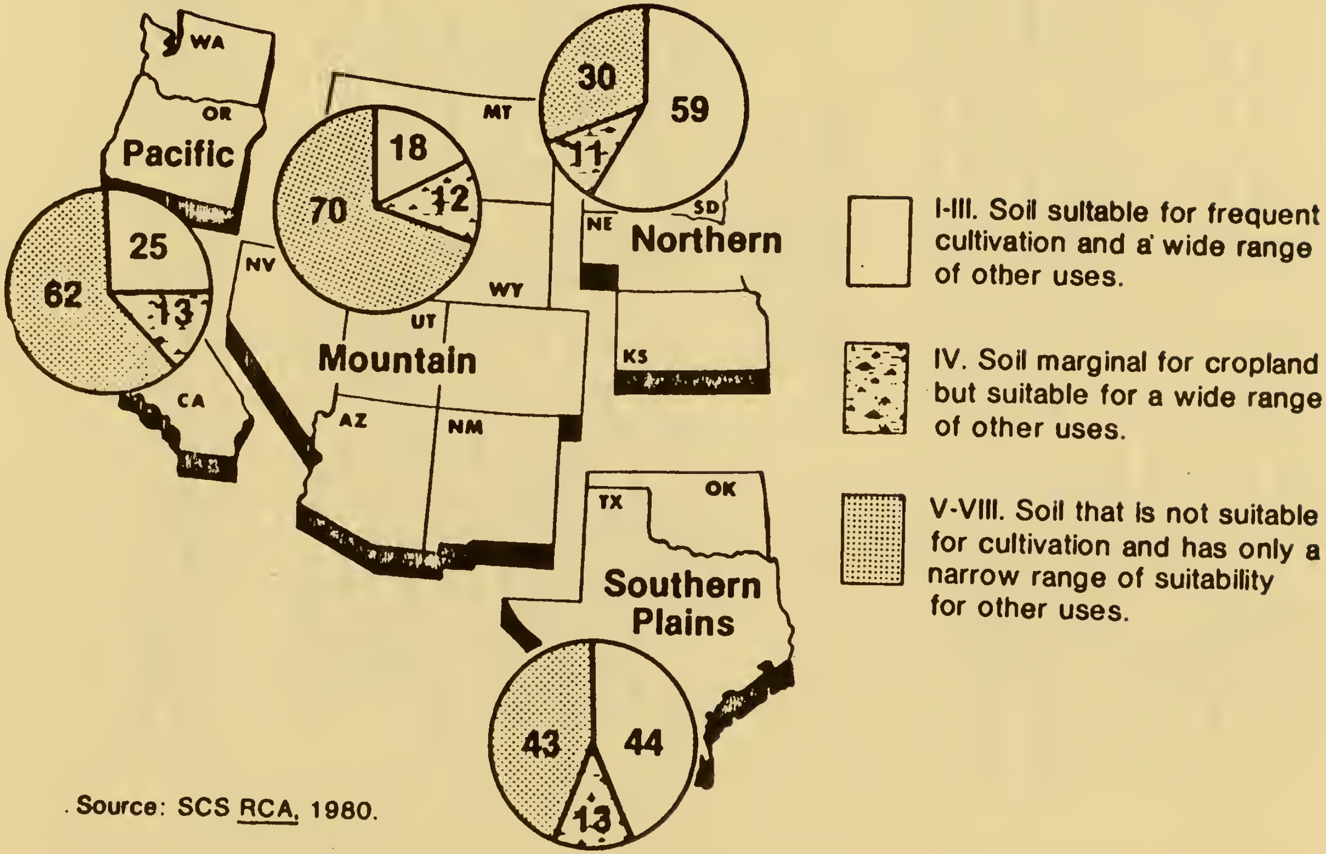
c. Capability Classification

Soil is classified by agricultural suitability into land capability classes I-VIII, which are defined in the glossary. Higher numerals indicate greater limitations and narrower choices for agricultural use. Figure C-1 shows the relatively small amount of privately-owned land suitable for cultivation in the 17 Western States. Comparable data for federally owned land is not available; however, it is generally acknowledged that a larger proportion of federal land is in classes IV through VIII.

It is a BLM goal to have soil surveys for federal lands completed by 1989. The USDA is assessing land capability classification of these same lands.

Figure C-1

Percentages of soil in capability classes I-VIII, by farm production region.



Source: SCS RCA, 1980.

Introduction

The main characteristic of the hydrology of arid and semiarid regions is the scarcity of the water circulating through the system. Since evaporation exceeds precipitation, an imbalance between supply and demand results when development, agricultural or other, is attempted. To compensate for these differences, large waterworks to impound and transfer surface waters have been built, and groundwater, the other basic and sometimes unique supply, has been tapped through the years. In some cases, groundwater is exploitatively managed, resulting in the sustained mining of the resource. From these conditions, actual and potential conflicts between old and new water uses and users have emerged that will have to be resolved in order to maintain or regain the good health of our arid regions.

Input to the System

(1) Surface Water

Input into the hydrologic system is from precipitation in various forms which doesn't necessarily enter at the time or location of use. Rivers and other bodies of surface waters may have their sources far from their course and be fed by precipitation outside the drylands. Runoff from precipitation in the arid regions also augments the flow of rivers, but rainfall is highly variable in time and area affected. The intensity of precipitation is usually the important factor in the runoff occurence in arid and semiarid lands as the duration of precipitation is generally short. Topographic and geological factors such as degree of slope, soil and rock morphology, and other aspects also affect runoff. Snowmelt from mountains represents a large component of the runoff volume.

The prinicipal rivers of the Western U.S. which receive precipitation runoff and from which water is withdrawn to satisfy human needs, and the major drainage basins are shown in figures D-1, D-2 and in table D-1.

(2) Ground Water

Ground water is an important source of water supply in the Western States. It is estimated that there are approximately 6.2 million acre-feet of water in storage at depths of 50 to 200 feet in the 11 Western States (BuRec, 1975). However, the amount recoverable is not known because of unanswered questions concerning location of supplies with respect to users, physical data in depth and nature of aquifer, pumping costs, ground water quality, and social policies toward mining ground water.

Ground water resources are located in aquifers that also are fed by precipitation. In some cases, the rainfall occurred over long periods of time and slowly accumulated in porous underground formations. Because aquifer recharge is so slow, this resource should be treated as nonrenewable, and in fact, we are mining ground water in several locations throughout the Great Plains and Western States (See figures D-3 and D-4).

Two types of aquifers are: consolidated or rock aquifers, and unconsolidated aquifers. The kinds of consolidated aquifers in the Western U.S. are mainly sandstone, carbonate rock, a combination of both, and volcanic rock. The unconsolidated aquifers, which are extensive throughout the West, generally have specific yields ranging from 10 to 20 percent of volume but a wide range of permeabilities due to varying size and distribution of interstices between the grains. Beds of sand and gravel commonly yield a few hundred to a few thousands gallons per minute of water to wells.

Volcanic rocks, primarily basalt, occurring mainly in the Northwest generally have low specific yields, ranging from less than 1 percent to about 3 percent, depending on the width and distribution of fractures. Yields of a few hundred gallons per minute of water from wells in sedimentary rocks, especially limestone and dolomite, are common. Consolidated sandstone contains excellent aquifers in parts of the Great Basin, the western Missouri River, and the Rio Grande regions. Yields of wells completed in limestone commonly range from a few hundred to a few thousand gallons per minute. The yields of wells completed in sandstone generally range from a few ten to a few hundred gallons per minute (gal/min). The yield of wells completed in shale generally is less than 10 gal/min. Crystalline rocks, widespread throughout the Rocky Mountains, generally yield less than 10 gal/min to wells, but they do provide adequate water for domestic supplies at many mountain homesites.

On the Great Plains, there is a large system of ground water in unconsolidated sand and gravel aquifers. Most of the large-scale pumping for agricultural use occurs in this type of aquifer. In Nebraska alone, there are 12,000 center-pivot irrigation systems, their number growing by 40-60 percent annually. Water use is estimated at 407,000 gallons per acre per year. There are also large concentrations of wells in the central California valley, in the Phoenix-Tucson area of Arizona, and on the Texas High Plains.

Output from the System

Hydrological output from the system includes evaporation, evapotranspiration, seepage and runoff.

Evaporation and evapotranspiration represent significant water losses from water surfaces, soil, and plants, effectively reducing the amount of available water in an already water-deficient region. Plants transpire water by taking it from the soil through the root system and by releasing humidity through their leaves. It has been calculated that crops under irrigation consume 41% of the gross diverted water by evapotranspiration. See figure D-5. Uncontrolled growth of certain plants such as phreatophytes which transpire large quantities of water can drastically reduce the water available for desirable plants.

The loss of water by seepage into the ground under rivers and reservoirs also is significant. Most of this water does not percolate to aquifer formations from which it could be pumped out and used, so it is unavailable.

Runoff is the largest output from the system and may be defined as the precipitation that eventually flows into streams, either as surface runoff or as runoff from ground water. Rainfall that reaches the surface of the ground initially infiltrates the soil, but once the capacity of the surface to hold water is exceeded, water begins to flow across the ground in trickles or sheets under the influence of gravity. This is surface runoff. Surface runoff increases from small rivulets at the beginning of a rainstorm to a steady torrent if the rain lasts long enough to saturate the storage mechanisms in and on the soil. Toward the end of a prolonged rain, nearly all of the water that reaches the ground joins the surface runoff.

In contrast to the rapid variation of surface runoff in response to precipitation, ground water runoff provides a much steadier flow of water to streams (Muller 1974).

Runoff from ground water supplies the base flow that maintains rivers through periods of drought, however, base flow is rather insignificant in arid and semiarid lands (See figures D-6 to D-9).

In the dry Western States, the unpredictable, erratic intensity of rainfall, sometimes in conjunction with unfavorable soil traits, may increase the amount of runoff leaving the system, thus decreasing the available moisture needed for plant production. Figure D-10 shows the variability of flow of the Colorado River at Lee Ferry, Arizona over 78 years.

Table D-1

Comparative Water Supply of Principal Western River Basins (mgd)

Water Resources Council Region	Current Streamflow[1] at Outflow Point[2]	Natural Outflow[3] at Outflow Point
Missouri Region	44,100	61,525
Arkansas-White-Red Region	62,600	67,694
Texas-Gulf Region	28,270	35,626
Rio Grande Region	1,230	5,309
Upper Colorado Region	10,000	13,956
Lower Colorado Region	1,550	13,351
Great Basin Region	2,562	5,976
Pacific Northwest Region	255,270	268,523
California Region	47,375	68,050

[1] *Current Streamflow* - Mean flow for 1975, derived from historical data; data includes effects of consumption, water transfers, evaporation, and ground-water overdraft.

[2] *At Outflow Point* - All streamflow measured at the downstream edge of the subregions and regions.

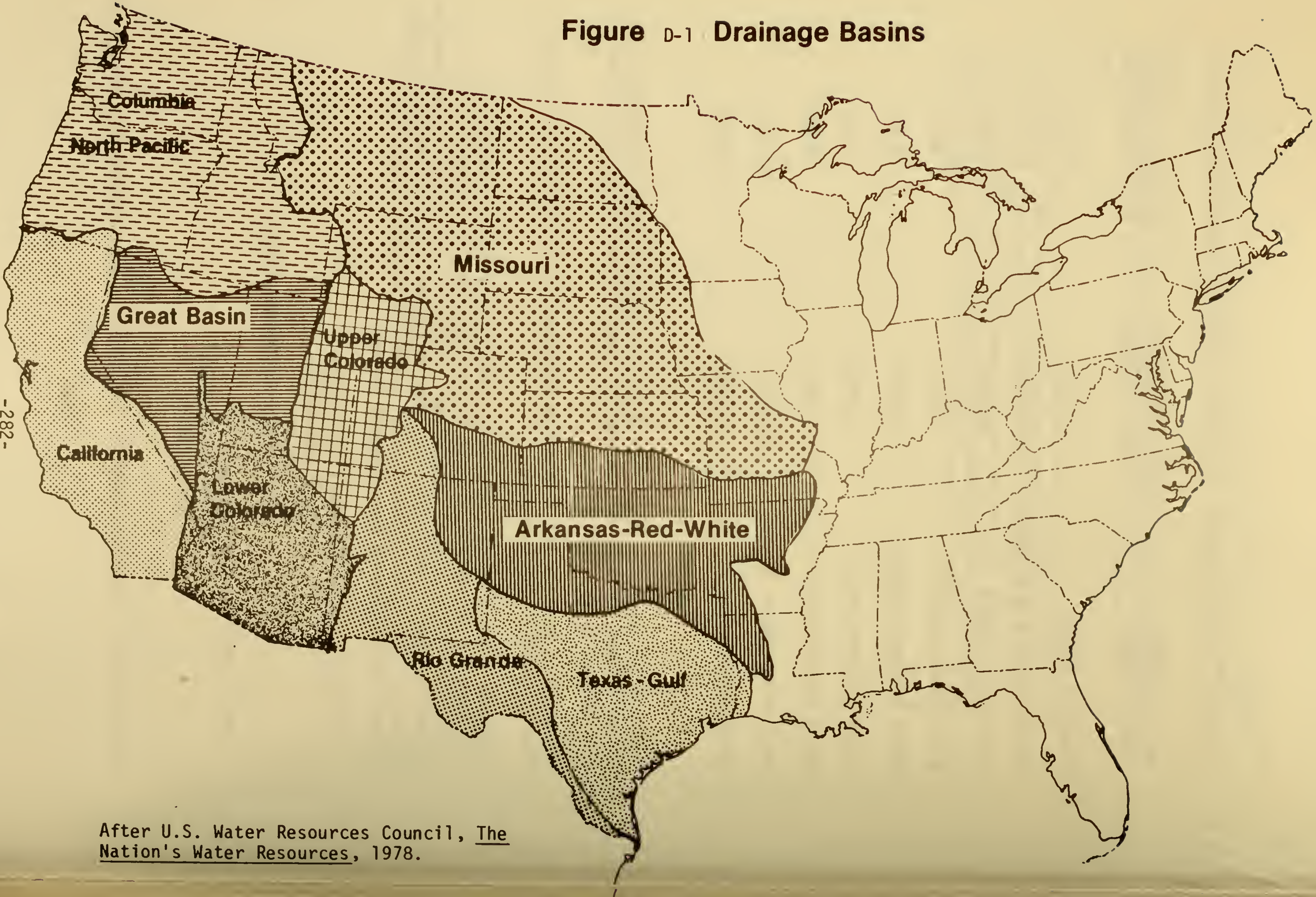
[3] *Natural Outflow at Outflow Point* (natural available streamflow) - Estimate of streamflow without artificial manmade constraints for comparison with current streamflow. Natural flow indicates the average potential runoff available from precipitation before introducing human effects. It is not truly natural stremflow because vegetation and runoff patterns have been altered by man.

natural outflow = current streamflow
+ total depletions
- net imports
- ground-water overdraft where

total depletions = consumption
+ net evaporation
+ net exports

Source: Water Resources Council, The Nation's Water Resources, Vol. 3, 1978.

Figure D-1 Drainage Basins



After U.S. Water Resources Council, The Nation's Water Resources, 1978.

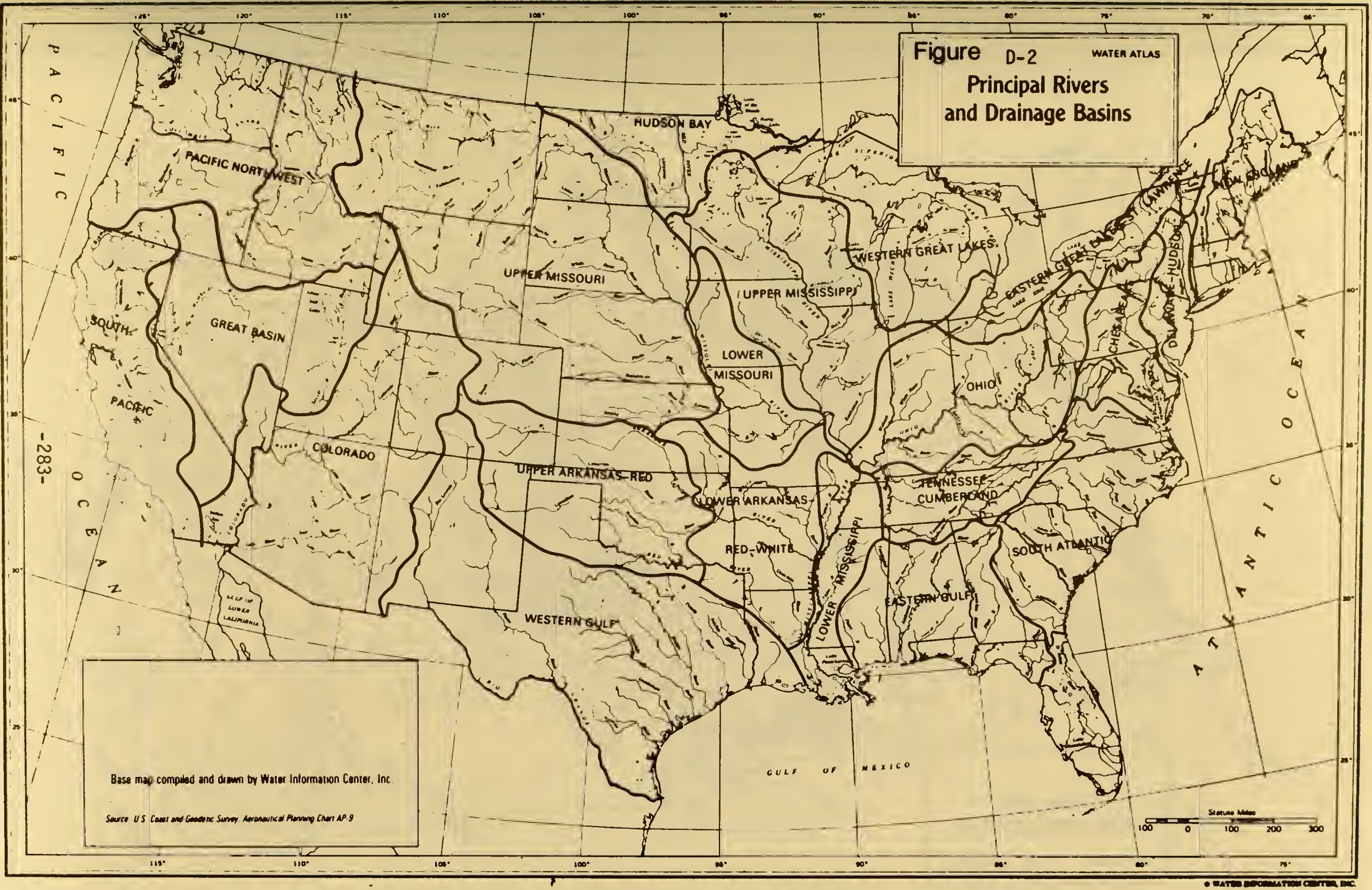


Figure D-2 Principal Rivers and Drainage Basins

Base map compiled and drawn by Water Information Center, Inc.

Source U S Coast and Geodetic Survey, Aeronautical Planning Chart AP-9

Source: James L. Geraghty, et al., Water Atlas of the U.S., Port Washington, NY: Water Information Center, 1973.

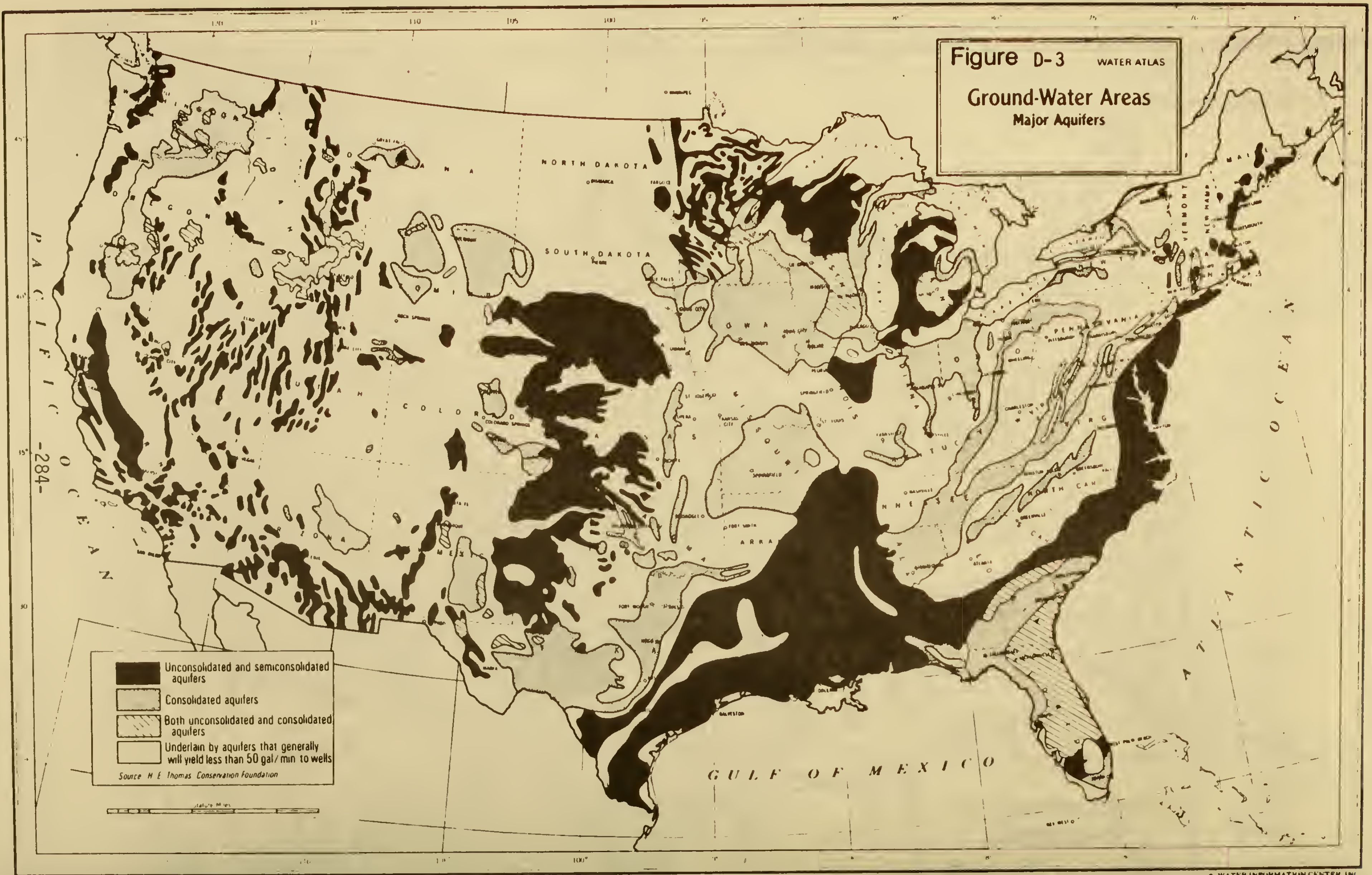


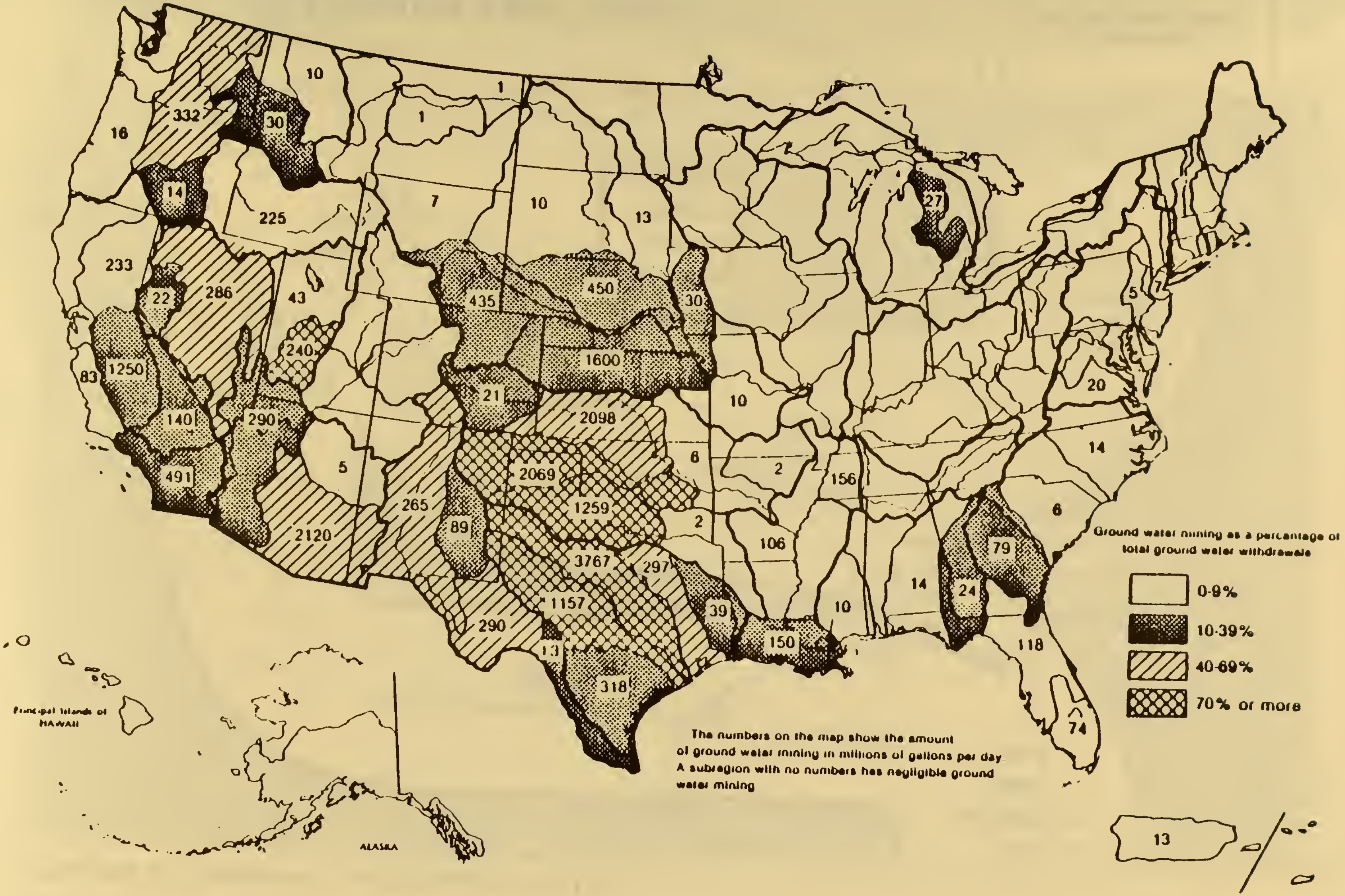
Figure D-3 WATER ATLAS

Ground-Water Areas
Major Aquifers

Unconsolidated and semiconsolidated aquifers
Consolidated aquifers
Both unconsolidated and consolidated aquifers
Underlain by aquifers that generally will yield less than 50 gal/min to wells
Source H. E. Thomas Conservation Foundation
Statute Miles
NORTH DAKOTA
SOUTH DAKOTA
IOWA
PENNSYLVANIA
VERMONT
NEW HAMP
GULF OF MEXICO
PACIFIC OCEAN
ATLANTIC OCEAN
Base Map by U S C & G S
© WATER INFORMATION CENTER INC

Source: James L. Geraghty, et al., Water Atlas of the U.S., Port Washington, NY: Water Information Center, 1973.

Figure D-4

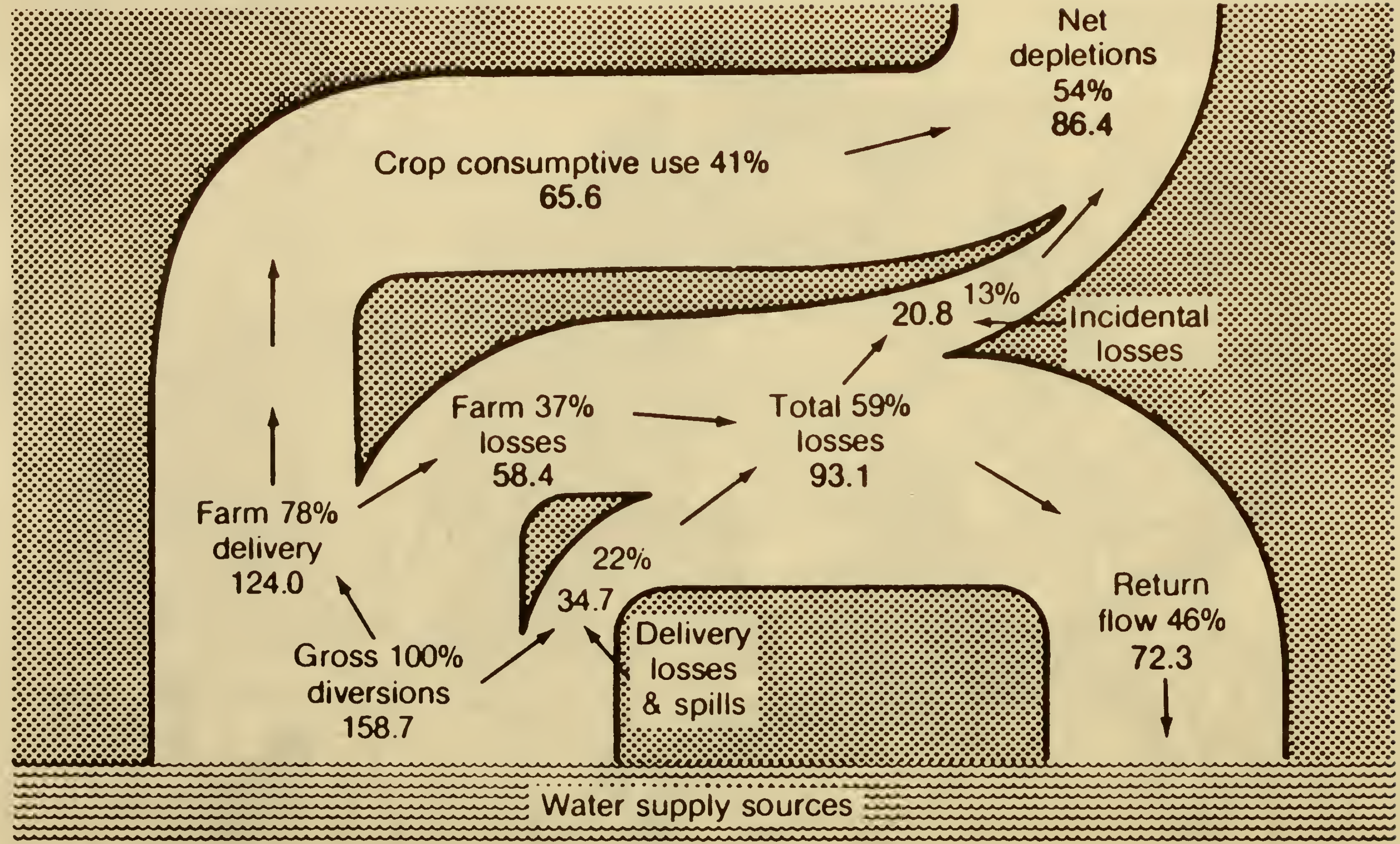

Ground water mining as a percentage of total ground water withdrawals
0-9%
10-39%
40-69%
70% or more
The numbers on the map show the amount of ground water mining in millions of gallons per day. A subregion with no numbers has negligible ground water mining
Principal Islands of HAWAII
ALASKA
10
1
332
30
1
16
14
225
7
10
13
27
233
22
286
43
435
450
30
5
7
240
1250
83
1600
21
20
140
290
2098
10
14
491
5
265
2069
6
2
156
1259
6
89
2120
2
106
79
3767
297
24
14
1157
10
39
290
150
118
13
318
74
13

Areas of ground water mining, "1975."

Source: U.S. Water Resources Council, The Nation's Water Resources, 1978.

Figure D-5

(Percent of Diversions - Mil. Gallons Per Day)



Irrigated water budget.

Source: USDA, RCA, 1980.

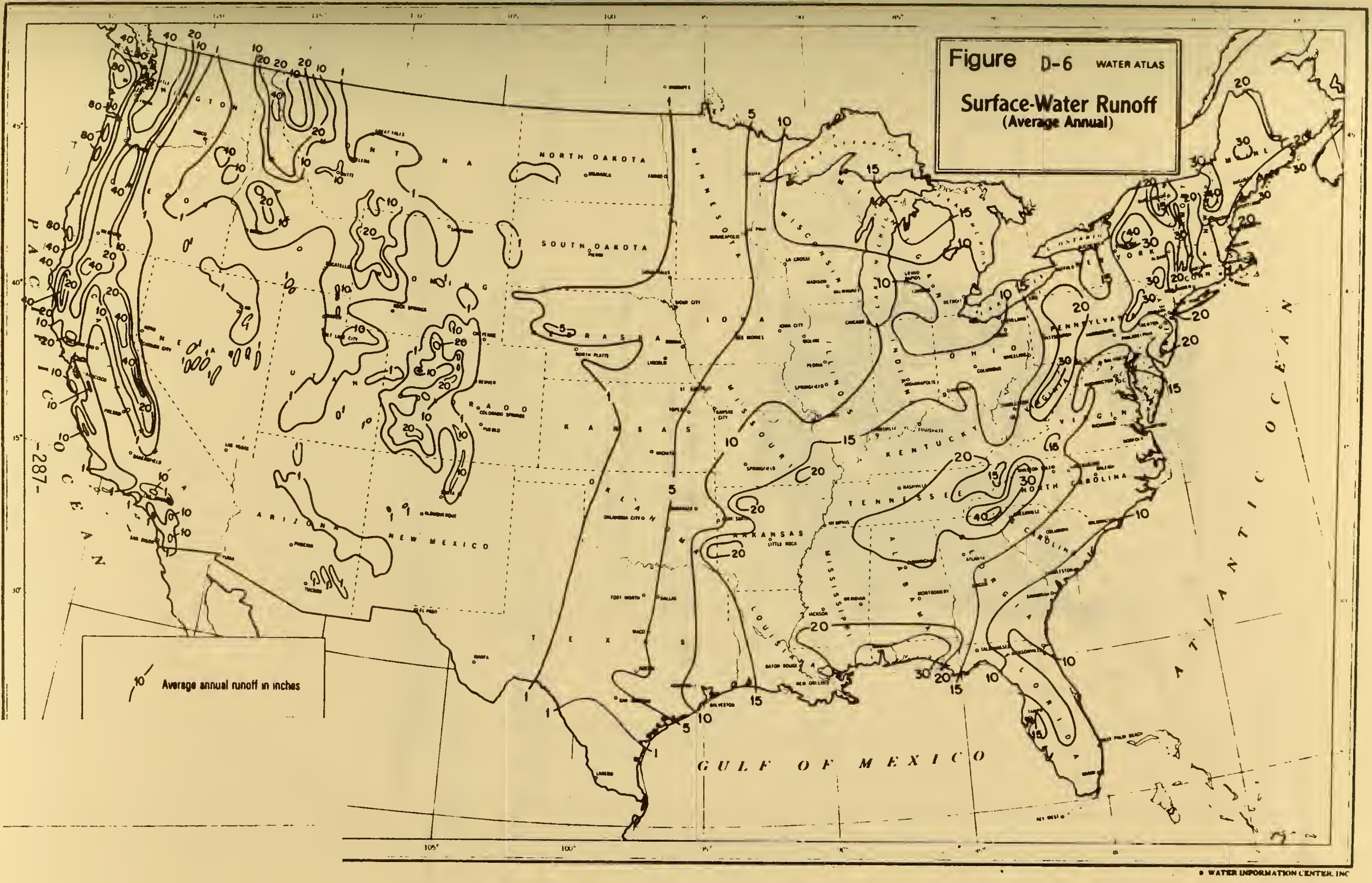
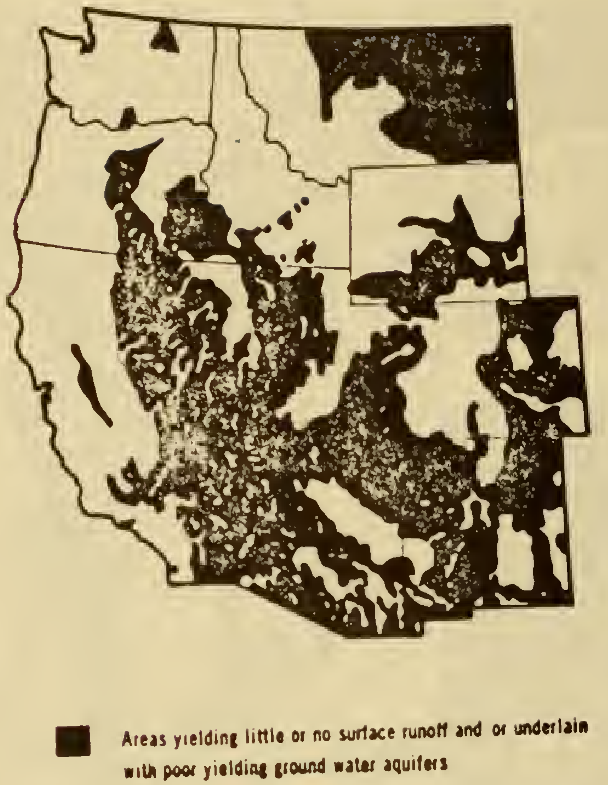


Figure D-6 WATER ATLAS

Surface-Water Runoff
(Average Annual)

Source: James L. Geraghty, et al., Water Atlas of the U.S., Port Washington, NY: Water Information Center, 1973, from U.S. Geological Survey data.

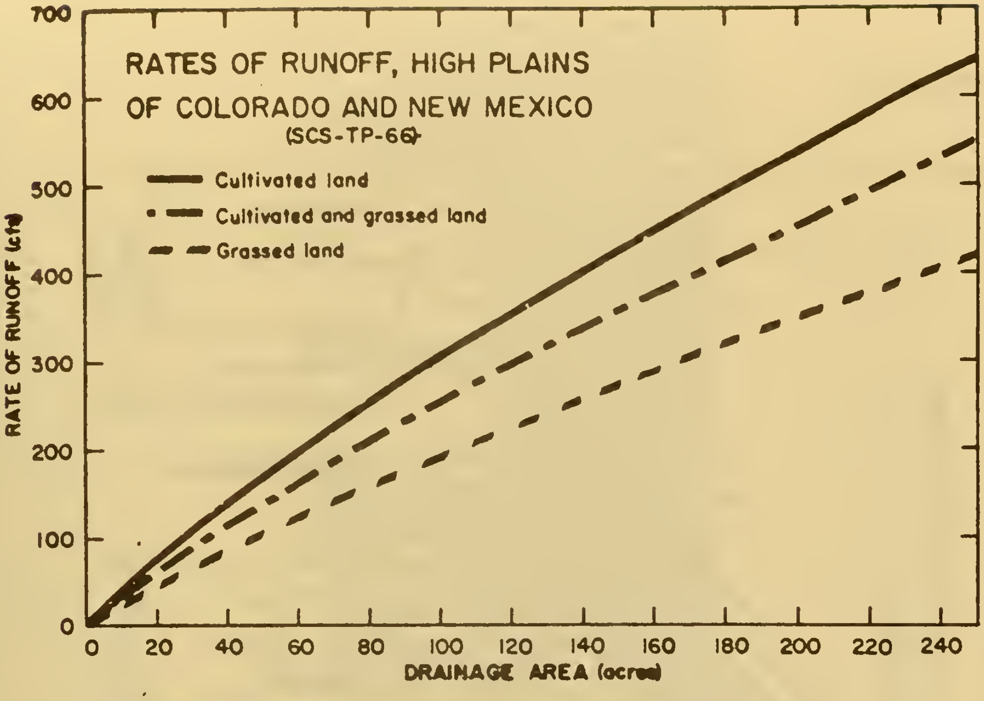
Figure D-7


■ Areas yielding little or no surface runoff and or underlain with poor yielding ground water aquifers

Areas with limited water supplies for small communities.

BuRec, USDI
Source: / Critical Water Problems Facing the Eleven Western States, April, 1975.

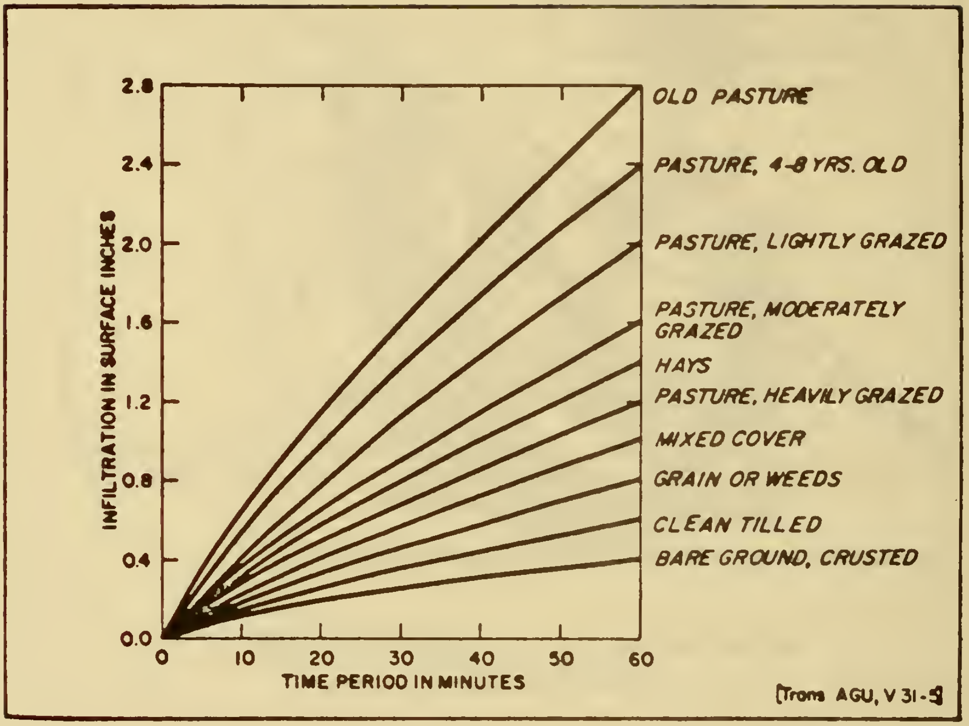
Figure D-8



Land use and treatment effect on 25-year runoff frequencies.

Source: Walter L. Moore and Carl W. Morgan, Effects of Watershed Changes on Streamflow, Austin: Center for Research in Water Resources of the University of Texas, 1969.

Figure D-9

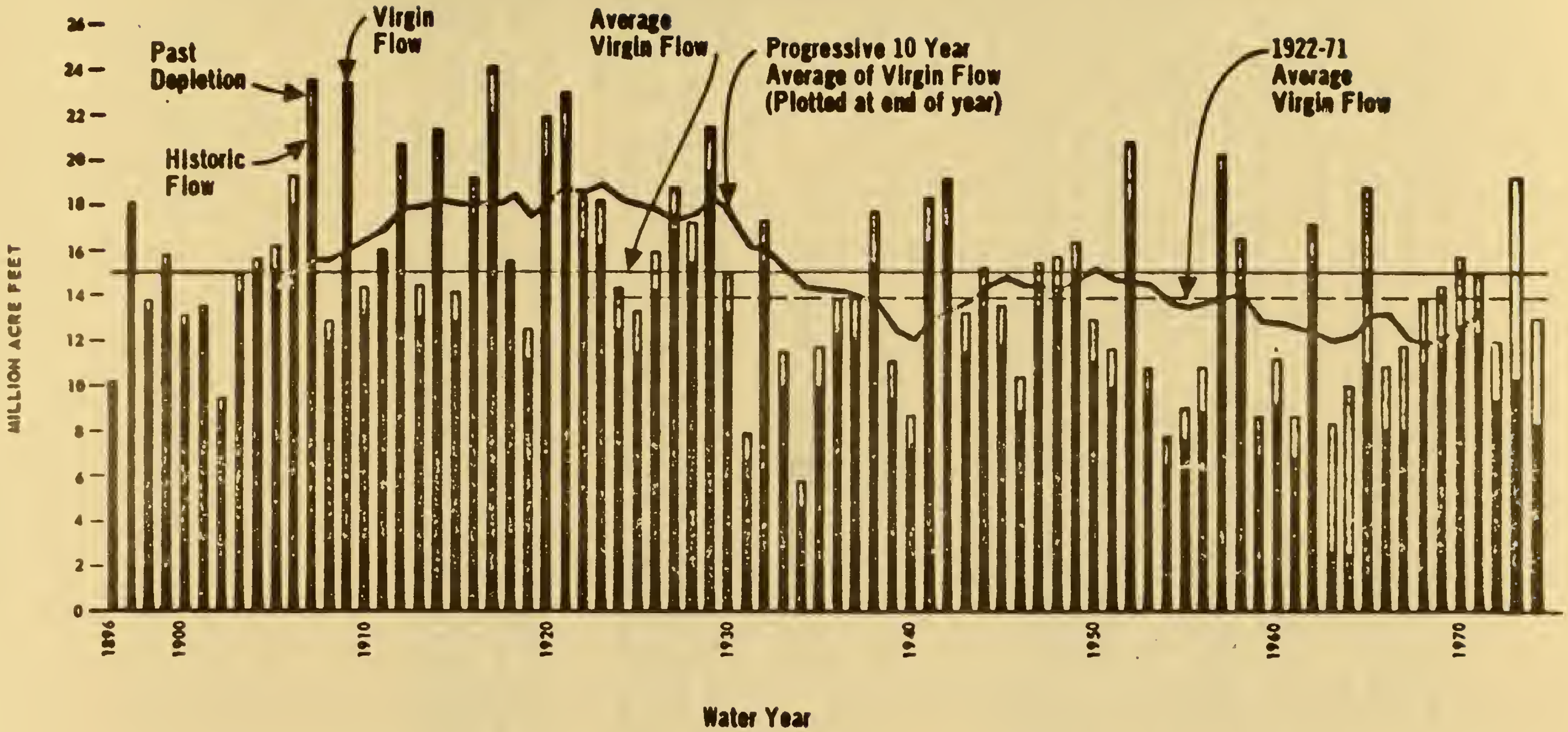


[from AGU, V 31-5]

Mass infiltration on Cecil, Madison, and Durham soils based on infiltrometer data.

Source: Walter L. Moore and Carl W. Morgan, Effects of Watershed Changes on Streamflow, Austin: Center for Research in Water Resources of the University of Texas, 1969.

Figure D-10



Colorado River flow at Lee Ferry, Arizona.

Source: BuRec, USDI, Critical Water Problems Facing the Eleven Western States, April 1975.

Introduction

Desertification affects the biological as well as the nonbiological components of an ecosystem because the conditions of soil, water, flora and fauna have a direct effect on one another. To better understand the impact of the desertification processes, a general description of the ecoregions of the arid domain is presented in this chapter. The ecoregions presented here (Figure E-1) are simplified versions of those presented in Robert G. Bailey's book Description of the Ecoregions of the United States. In general, the regions overlap with the Great Plains, Mountain, and Pacific regional divisions (Figure III-1) and also with the geographical regions (Figure A-1); however, the overlaps are not exact. There has been no attempt to separate and indicate either pristine or present conditions, although some land is in nearly pristine condition having minimal disturbance, while other land is almost completely altered by human modification.

Ecoregions

a. Northwest Grassland Ecoregion

Vegetation: This ecoregion was once dominated by grasses, but now large areas are cultivated for wheat production. Most of the remainder of the region is vegetated by sagebrush, which has proliferated because of heavy grazing of more palatable plants by both domestic and wild animals.

Fauna: Wild animals which can inhabit the sagebrush cover include pronghorn antelope, deer, bobcats, coyotes, and species of birds and reptiles suited to shrub vegetation existence. The grazing wildlife are often in competition with the domestic animals for available forage.

b. California Ecoregion

Vegetation: The vegetation of this ecoregion is very distinct because of the extreme seasonality of precipitation between the wet winter and the dry summer. The vegetation is predominately hardleaved evergreen trees and shrubs called sclerophyll woodland. The type is called sclerophyll because the leaves contain thick, hard walls in their cells to help prevent excessive mositure loss and wilting during the extremely dry and often hot summers. The other vegetation of this ecoregion was once predominately grassland, but it has been largely replaced in sections by fruit and vegetable crops and extensive acreage of grains. Large areas of shrubs such as creosote and chaparral exist in the southern part of the region.

Fauna: The larger wildlife mammal species such as the California grizzly, wolf, and the larger ungulates (hoofed mammals) have generally disappeared from the region due to urbanization and intensive agricultural use of the land. Large domestic livestock are prevalent, with California ranking seventh in the nation in both cattle and sheep production in 1977 (USDA 1977). Wild horse and burro populations are significant. Smaller wild mammals such as coyote, rabbits, and rodents are able to live near the cities and in the woodlands. Several species of birds and reptiles are present in the region, but amphibians and fish can exist only at large perennial reservoirs because small reservoirs often evaporate completely during the hot, dry summers.

c. Western Shrub and Brush Ecoregion

This large region is divided into smaller sections by the type and density of shrub and/or brush:

1. Great Basin
2. Colorado Plateau
3. Southwestern U.S. Desert
4. Chihuahuan Desert
5. Wyoming Basin

(1) Great Basin

Vegetation: The Great Basin section of this ecoregion is dominated by sagebrush and other shrubs, such as shadscale, fourwing saltbrush, and greasewood, which have the salt tolerance necessary to withstand the salinization of soil produced by the drainage to interior basins. On the slopes of the hills and mountains of this section, the vegetation may be vastly different due to lower salinity, summer temperatures, and greater precipitation.

Fauna: Scarcity of potable water and desirable forage makes large wild species of mammals such as deer sparse. Jackrabbits, kangaroo mice, snakes, and hawks, which are adapted to dry environments, are relatively plentiful. Much of this area is federally owned and livestock grazing permits are issued. Wild horses and burros also graze in the area.

(2) Colorado Plateau

Vegetation: In the lower altitudes of the Colorado Plateau section, vegetation types include cactus and yucca, sparse grasses, and sagebrush. Higher altitudes of this dry plateau are chiefly covered by pinyon and juniper, woodlands while pine and spruce forests are prevalent in the higher, more moist locations. Highly variable and erratic precipitation makes dry farming impractical, as unreliable water resources for irrigation hamper large cropping efforts. Most of the land is then used for livestock grazing.

Fauna: Because of the proximity of the mountain forests and woodlands, larger wild animals such as elk and pronghorn can be found in this region, though they seldom range deeply into the arid lowlands. Animals such as jackrabbits and rattlesnakes which are adapted to arid lands live in the lower altitudes. Domestic cattle and sheep graze the short grasses and some of the brush species.

(3) Southwestern U.S. Desert

Vegetation: In this section, which encompasses the U.S. portions of the Mojave, Colorado, and Sonoran Deserts, there is only sparse vegetation with bare ground conspicuous. Cacti and shrubs such as creosote and mesquite predominate. Upland areas may contain plants such as Joshua tree and juniper. There is livestock grazing in some areas, but the shortage of water precludes most agricultural endeavors.

Fauna: Many species of desert birds and reptiles live in this section, but there are very few large animals of any type. Most wild animals are small and are nocturnal burrowers, thus avoiding the heat of the desert day.

(4) Chihuahuan Desert

Vegetation: In the U.S. portion of the Chihuahuan Desert thorny shrubs are the dominant vegetation. Short forage grasses are found in association with the shrubs, but this region has a low carrying capacity. Mesquite, creosote, and ocotillo are commonly found. Phreatophytes, such as mesquite, tap the water table with their deep root systems but waste water by rapidly transpiring it.

Fauna: In addition to the small desert animals found in the Southwestern U.S. desert, larger animals such as deer, antelope and javelina are found in the Chihuahuan Desert section of the Western Shrub and Brush Ecoregion in the riparian vegetation of the intermittant streams. A limited number of domestic livestock are grazed here.

(5) Wyoming Basin

Vegetation: The vegetation of this basin is a mixture of short grasses and shrubs such as sagebrush, shadscale, or alkali-tolerant greasewood. Some wheat is dry-farmed, and some feed crops are irrigated. There is limited livestock production.

Fauna: In this sparsely populated and largely undeveloped section wildlife flourishes. The low carrying capacity of the land, however, intensifies the competition for available forage between wildlife and domestic livestock. Coyotes, antelope, and the large cats such as mountain lion and bobcat are the primary larger species of wild animals, and the smaller species include ground squirrels, rabbits, and rodents. Migratory animals use this basin for breeding, feeding, and resting during their travels. Migratory waterfowl ar common here.

d. Rocky Mountain Ecoregion

Vegetation: In the Rockies, altitude effects the amount of precipitation, temperature, and prevailing winds, thereby creating belts or zones of different vegetation. The highest zone is above the "timber line" and has the short grasses and sedges characteristic of tundra vegetation. The next lower zone is one of forests of spruce and fir trees. The forests of the next lower area are of pine and fir trees. Next is a zone of shrub woodlands dominated by pinyon and juniper. Finally, in the dry valleys and plains beyond the mountain foothills are the arid sections of grasses, shrubs and cacti. Few crops are cultivated here, with grazing being the principal agricultural occupation.

Fauna: Large wild animals are common in this altitudinal zone's vegetation. Bears, elk, and mountain lions are representative of the large mammal wildlife, while squirrels, chipmunks, and rodents are representative of the smaller species. Domestic livestock are grazed on the forage grasses of the middle vegetation zones. Many varieties of birds, reptiles, amphibians, and fish inhabit one or more of the vegetative zones of the Rocky Mountains.

e. Great Plains Steppe Ecoregion

Vegetation: The ecoregions discussed here and the physical regions discussed in the geographical data section do not exactly coincide. The western Great Plains, while divided mainly by topography into three physical regions-the Western Great Plains Rangeland-was once almost completely covered by short grasses. The common name of typical grass of the area, buffalo grass, suggests the historical importance of this mammal in the region. Though grasses predominate, they do not cover all the land, and bare spots are common. While the greater part of this region is used for grazing, there is extensive acreage in dry-farmed wheat and some irrigated feed crops along the streams.

Fauna: Wild animals such as deer and antelope, rabbits, and prairie dogs are plentful throughout the section, and are preyed upon by coyotes and other predators. Birds such as grouse are common, and the livestock grazing development of the area has led to stock ponds useful to migratory waterfowl.

f. Great Plains Prairie Ecoregion

Vegetation: In contrast to the short grass ecoregion described above, this ecoregion is dominated by tall grasses such as porcupine grass, little bluestem, and western wheatgrass. The boundary which separates the tall grasses from the short grasses is indistinct and constantly changing with the precipitation variations of the region (McGinnies no date). There are some areas of mixed short and tall grasses, but large vegetation such as trees is sparse throughout the region.

Wheat production dominates the agricultural output, with other grains such as sorghum being of some importance in the southern part of the region. Irrigation from ground water sources is used for local fruit, vegetable and cotton production. Grazing is still an important agricultural activity, but feedlot cattle production is increasing.

Fauna: The ecoregion is populated by a variety of mammals which range in size from domestic cattle and antelope through sheep, coyotes, and badgers to the small rodents and rabbits. Birds and reptiles are plentful, as are amphibians and fishes which are abundant in and near the steams that cross the area.

g. Southwest Plateau Brushland Ecoregion

Vegetation: This area is characterized by grasses mixed with shrubs. The grasses are predominately bluestem, buffalo grass andgrama, and the shrubs (at higher elevations) are mainly mesquite and juniper. Grazing is the dominate argicultural activity, but crops such as cotton, wheat, and other grains are grown where conditions permit. The lower Rio Grande Valley is warm and moist enough to provide for citrus fruit and winter vegetables.

Fauna: Livestock are predominant in this area with much of the sheep production of the United States located here. Wildlife such as deer, wild turkeys, armadillo, and quail, as well as several reptile species, are abundant.

h. Riparian Ecosystems

While riparian ecosystems throughout the western United States are limited in size and scattered throughout the ecosystems described above, their ecological importance merits special attention.

A riparian ecosystem consists of the stream and streamside flora and fauna which may lace its way though a very different type of environment. Dryland riparian ecosystems are extremely important, highly productive, linear oases in the surrounding arid areas.

Riparian ecosystems provide soil and water resources for irrigated agriculture and livestock production in regions where the moisture regimen and carrying capacity would not otherwise provide them. Recreational uses of riparian ecosystems are also important, with fishing, cannoeing, birdwatching and other activities dependent on the stream. In general, dryland riparian systems facilitate the exploration of the adjacent uplands, thus enhancing the productivity of neighboring arid areas. This type of ecosystem often contains the only large vegetation species, such as cottonwood trees, in areas where grasses and shrubs predominate.

For wildlife, riparian ecosystems provide food, water, shade, cover, and migration corridors for both resident and migratory species. Further, amphibians and fish depend directly on the quality and quantity of the water in the system.

There are some issues and conflicts concerning the uses of riparian ecosystems that must be noted.

1. Human intervention may adversely impact the riparian ecosystem wildlife.

2. An impact on the system may be produced by channeling of streams for flood control. The meandering streams are straightened, and the biomass of riparian vegetation is thus effectively reduced.

3. Often in channeling, the steambeds are lined with concrete or other impermeable materials that prevent water seepage. Although water is provided dowstream, the riparian vegetation is strongly impacted, often irreversibly.

4. Programs to control the growth of phreatophytic plants, so as to reduce water losses caused by their abundant evapotranspiration, may result in the deterioration or less of wildlife habitat and in stream bank erosion.

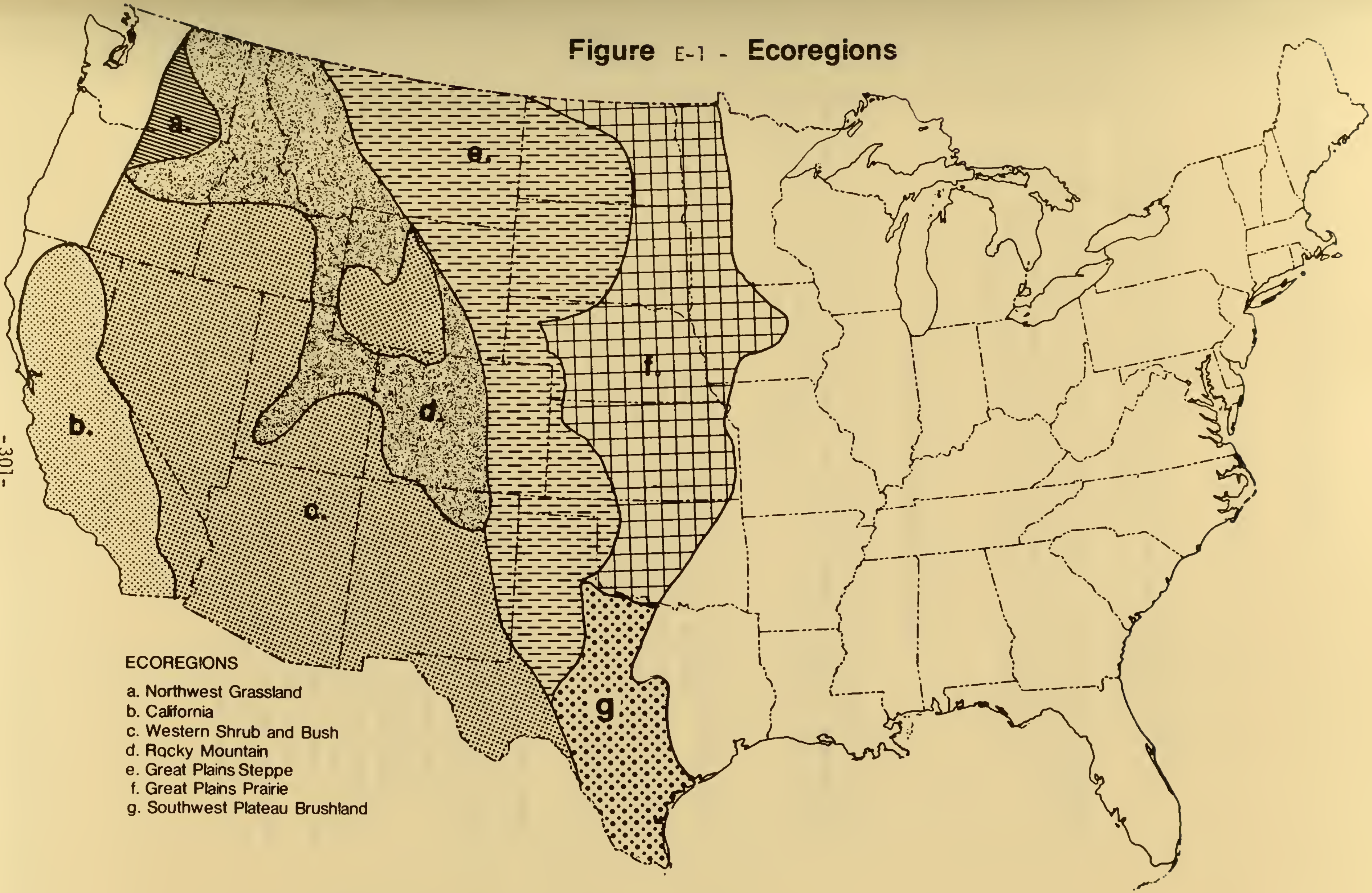
5. Disturbed riparian ecosystems may further deteriorate with the invasion by less productive exotic species, such as the tamarisk (salt cedar), which replace beneficial native cottonwood.

6. Reduced stream flow resulting from increased irrigation and municipal withdrawals imposes stresses on riparian flora. Even though some types of vegetation, such as cottonwind trees, can remain viable for up to two years without stream flow, they too will eventually disappear.

7. Frequent, often daily, fluctuations in dam water levels, due to releases of water for power generation, may damage downstream riparian ecosysems because of the periodic flooding and dessication plants and animals are subjected to.

The desirable characteristics of the riparian ecosystems are precisely the reasons for the excessive or exploitive use that may occur, causing serious and extensive degradation. Overgrazing, excessive logging (recently for firewood), unsound ORV use, diversion and export of water resources, among other activities, have contributed to the reduction of the western riparian ecosystems to an estimated 10% of their original area (Johnson 1978).

Figure E-1 - Ecoregions



After Robert G. Bailey, Description of the Ecoregions of the United States, USDA, Forest Service, 1978.

Appendix F: Effect of Social Structure

a. Introduction

The composition of a society and the conditions under which it functions affect the reactions of a given population in legislating, funding, and implementing policy proposals.

The perceptions, real or not, of the impact that certain proposed or ongoing activities may have on the survial and the fulfillment of individual and community needs and desires are crucial in deciding whether to undertake and whether to continue the activities in question.

b. Factors Affecting Decisions

Some of the human factors influencing the decision-making process are age, cultural background, level of income, type to community activities, population stability, etc. Some of these factors are reflected in tables F-1 through F-4.

The combination of these factors or the effects of a single one may result in different decisions which could affect environmental quality issues, job opportunities, recreation activities, development of natural resources, community growth, etc. For example, population figures, presented in Tables F-5 through F-8, indicate that the Indian population is increasing slowly and becoming more urban in residence.

This influences the land use of reservations. The main concern, in general, is who benefits and who pays the bill, and the perception of the financial distribution, which may or may not be the correct one, influences the selection of options. In a situation in which there are losses of an economic, ecological, political, or any other nature, that may threaten individual and/or community survival, security, esthetic and intellectual needs, the options to be followed are generally: (a) to modify the cause so as to reduce the frequency of events that result in losses; (b) to modify the process by which the losses occur or to channel the forces of the event; or (c) to modify the loss potential so as to reduce the losses after the event has occurred (Cochrane 1875). The decisions to follow either, some, or all of these paths, and to what extent and direction, are functions of the factors mentioned above and others.

In the case of desertification, its social impact was visible and somewhat measurable during the dustbowl years. The social, economic and technical changes of the last decades have spurred the belief that the problem no longer exists or that it has been greatly mitigated. Unfortunately these perceptions generate attitudes, values, and hence decisions that are not as effective as they should be in dealing with the still-present desertification problems.

Table F-1

Population and Population Density

Region	Population x1,000							Population per Square Mile		
	1930	1940	1950	1960	1970	1977	2000*	1930	1970	2000*
Great Plains (ND, SD, NE, KS, OK, TX)	12,854	13,153	14,448	16,811	18,780	20,870	26,487	20.3	29.6	41.8
Mountain (MT, ID, WY, CO, NM, AZ, UT, NV)	3,702	4,150	5,075	6,855	8,282	10,031	14,732	4.3	9.7	17.2
Pacific (WA, OR, CA)	8,194	9,733	14,486	20,339	25,453	27,930	34,540	25.7	79.8	108.2

*Assumes cohort fertility will approach 2.1 births per woman, and that the 1970-75 interstate migration patterns will continue.

Source: U.S. Bureau of the Census: Statistical Abstracts of the U.S., 1978.

Table F-2

Percent Population by Age

Region	1960				1977			
	Under 5 Years	5-19 Years	20-64 Years	65 Years & Older	Under 5 Years	5-17 Years	18-64 Years	65 Years & Older
Great Plains (States)	11.7	28.2	51.0	9.1	7.9	22.9	58.5	10.7
Mountain (States)	12.8	29.6	49.9	7.7	8.8	23.6	58.5	9.1
Pacific (States)	11.0	26.5	53.4	9.1	6.9	21.8	61.1	10.2
Total	1960: 44,005,000				1977: 58,831,000			

Source: U.S. Bureau of the Census, Statistical Abstract of the U.S., 1978.

Table F-3

Metropolitan and Nonmetropolitan Area Population*

Region	Metropolitan Area Population				Nonmetropolitan Area Population			
	Pop. x1,000		% of Region		Pop. x1,000		% of Region	
	1960	1976	1960	1976	1960	1976	1960	1976
Great Plains (ND, SD, NE, KS, OK, TX)	9,901	13,501	58.9	65.7	6,911	7,048	41.1	34.3
Mountain (MT, ID, WY, CO, NM, AZ, UT, NV)	3,672	5,933	53.6	60.4	3,182	3,886	46.4	39.6
Pacific (WA, OR, CA)	17,635	23,936	86.7	87.2	2,703	3,524	13.3	12.8

*Refers to 277 SMSA's as defined in Standard Metropolitan Statistical Areas, 1975, Revised Ed. (Dec. 1975).

Source: U.S. Bureau of the Census, Statistical Abstract of the U.S., 1978.

Table F-4

Employment Data, 1970

State	Number in the Civilian Labor Force	% of Civilian Labor Force Unemployed	Farm Workers the Civilian Labor Force
Arizona	640,000	4.2	17,947
California	7,992,168	6.3	162,217
Colorado	862,133	4.2	32,131
Idaho	271,593	5.2	29,224
Montana	260,649	6.2	28,465
Nevada	208,996	5.4	3,683
New Mexico	342,482	5.7	12,373
Oregon	837,078	7.0	31,016
Utah	399,162	5.2	11,715
Washington	1,338,513	7.9	41,344
Wyoming	129,577	4.8	11,061
Total	12,951,570	6.0	381,176

Source: U.S. Bureau of the Census, Statistical Abstract of the U.S., 1978.

Table F-5

American Indian Population in the Western States

	1960	1970
Great Plains	118,583	178,455
Kansas		8,672
Nebraska		6,624
North Dakota		14,369
Oklahoma		98,468
South Dakota		32,365
Texas		17,957
Mountain	188,004	235,439
Arizona		95,812
Colorado		8,836
Idaho		6,687
Montana		27,130
Nevada		7,933
New Mexico		72,788
Utah		11,273
Wyoming		4,980
Pacific	68,116	137,914
California		91,018
Oregon		13,510
Washington		33,386

Source: U.S. Bureau of the Census, Statistical Abstract of the U.S., 1978.

Table F-6

American Indian Population Figures

	1960	% of Total	1970	% of Total
Great Plains Region (States)	118,583	32	178,455	32
Mountain Region (States)	188,004	50	235,439	43
Pacific Region (States)	68,116	18	137,914	25
Total	374,703	100	551,808	100
Total Urban Pop.	104,917	28	248,314	45
Total Rural Pop.	269,786	72	303,494	55

Figures extrapolated from U.S. Bureau of the Census, Statistical Abstract of the U.S., 1978.

Table F-7

American Indian Population by Urban-Rural Residence

Year	Total	Urban	Rural
1960	524,000	146,000	378,000
1970	793,000	356,000	437,000

Figures rounded.

Figures concern the nation as a whole, but they are significant because a large majority of the American Indians live in the Western U.S.

Source: U.S. Bureau of the Census, U.S. Census of Population, 1960 and 1970, vol. 1.

Table F-8

American Indian Population Figures

	1960 % of Total	1970 % of Total
Great Plains Region	32	32
Mountain Region	50	43
Pacific Region	18	25
Total Urban	28	45
Total Rural	72	55

Figures extrapolated from U.S. Bureau of the Census, Statistical Abstract, 1978.

Appendix G:

Economic Use

The impact of desertification on arid and semiarid lands economic systems may be quite high, but data for these computations is scarce, sketchy and far from definitive. Nevertheless, the need for even a gross assessment of such impacts, specifically on the agricultural and supporting industries, should be underscored. The value of the total system as well as the costs of arresting desertification are also necessary to determine whether these efforts ar worthy of undertaking. Some current economic data is presented in tables G-1 and G-2.

What makes the evaluation of the impact localized desertification intensity and length especially difficult is the interdependence of all economic sectors and components, and the ripple effect that occurs throughout the system. Table G-3 shows the estimatd total annual impact of $100,000 loss in dryland crop production on Texas industries. The table reveals that by the time the $100,000 ripple has spread, it has enlarged to $374,000. A loss of this nature is far from uncommon in the Western U.S. due to the highly variable annual weather conditions. Table G-4 shows what has happened in the past when drought hit the Western U.S. in the 1930's and 1950's. Crop failures increased dramatically, and related business and services also suffered economic damage.

The energy budget of the argicultural and allied industries are of primary importance in deciding which management, conservation, and control practices should be adopted to cope with desertification when it occurs.

For example,

In Nebraska alone 4.5 million acres are now irrigated by center pivot irrigation systems. Each year, 83 million gallons of diesel fuel are necessary merely to drive the pivot, not including pumping of groundwater or other related energy-onsumptive uses. There are now near 40,000 center pivot irrigation systems, and these are increasing by 40 to 60% annually.

(Also see table G-5 and figures G-1 and G-2). The increased intense use of this land, plus the increasing demand on the groundwater supply and associated problems, such as salinity buildup, could lead to a desertification situation. In such a case the energy budget needed to augment water supplies and control salinity, added to the energy necessary to maintain the level of production (more fertilizers and pesticides, as well as water treatment costs) should be calculated, since these energy costs are important determinants in deciding on the continuation, termination or change of procedures.

Table G-1

Measures of Population and Economic Growth - United States

% Annual Rates of Increase

Year	Population	Gross National Product	Per Capita GNP	Disposable Personal Income	Per Capita Disposable Personal Income
1950	1.6	0.1	-1.6	1.7	0.1
1974	0.7	-2.2	-2.9	-2.6	-3.3
2000*	0.7	3.5	2.8	3.5	2.8

*Medium projection.

Source: USDA, RPA, 1975.

Table G-2

Trade - Sales and Payroll

(billions of dollars)

Region	Wholesale Trade			Retail Trade		
	Sales*		Payroll	Sales*		Payroll
	1963	1972	1972	1963	1972	1972
Great Plains	30.8	66.0	3.1	22.3	43.7	4.8
Mountain	9.9	21.3	1.2	10.1	21.5	2.5
Pacific	45.0	86.8	4.8	33.6	62.6	8.2

*All establishments

Source: U.S. Bureau of the Census, Statistical Abstract of the U.S., 1978

Table G-3

Estimated Total Annual Impact of $100,000 Loss in Dryland Crop Production on Texas Industries

	Selected Texas Industries	Amount Lost from Decreased Output of Dryland Crops
1.	Retail trade	$ 26,390
2.	Finance, insurance and real estate	19,300
3.	Other services and education	14,560
4.	Agricultural services	18,040
5.	Wholesale trade	14,280
6.	Agricultural chemicals	9,300
7.	Petroleum refining	9,120
8.	Electric services	2,630
9.	Motor freight and storage	3,360
10.	Communications	2,270
11.	All other sectors, incl. households*	254,750
		$374,000

*Includes the direct loss of $100,000

Source: ASCE, Water Conservation Needs and Implementing Strategies, 1979.

Table G-4

Cropland Used for Crops; Crop Failure

(millions of acres)

		Cropland Used for Crops	Crop Failure
Great Plains	1939	128.0	13.9
	1956	131.7	14.3
	1977	130.4	4.5
Mountain	1939	25.8	2.7
	1956	35.7	3.0
	1977	36.0	1.1
Pacific	1939	17.8	0.5
	1956	20.8	0.4
	1977	20.7	0.2

Note: 1939 and 1956 were the heights of the 1930's and 1950's Dust Bowls.

Source: Donald D. Duros and Evelyn T. Black, Changes in Farm Production and Efficiency, USDA, November 1978.

Table G-5

Energy Costs for Various Irrigation Systems (Diesel Fuel Only)

	Total Lift Feet	Field Eff. %	Pot. Eff.	Water per Acre Inches	Fuel/Ac. Gal.	Cost of Energy per Acre 1977	Cost of Energy per Acre 1979
Traveling Big Guns	389	70	75	17	68.7	$28.16	$56.32
Center-Pivot	273	80	85	15	42.5	17.43	34.86
Skid-tow	215	75	80	16	35.8	14.67	29.34
Gated Pipe w/o reuse	120	60	70	20	25.1	10.27	20.54
w/reuse	120	70	85	17	21.3	8.71	17.43
Auto-surface	120	85	92	14	17.5	7.18	14.35
Drip-Trickle	150	85	92	14	21.7	8.89	17.80

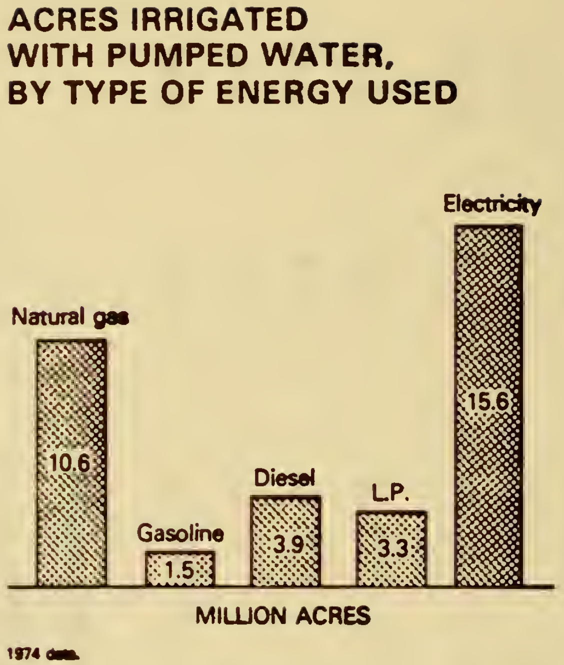
Based on: 100 ft. of lift from ground water reservoir;

12 inches of net water application;

$0.41 per gallon diesel fuel - 1977;
$0.82 per gallon diesel fuel - 1979.

Source: ASCE, Water Conservation Needs and Implementing Strategies, 1979.

Figure G-1


ACRES IRRIGATED WITH PUMPED WATER, BY TYPE OF ENERGY USED

1974 data.

Source: USDA, 1978 Handbook of Agricultural Charts.

Figure G-2

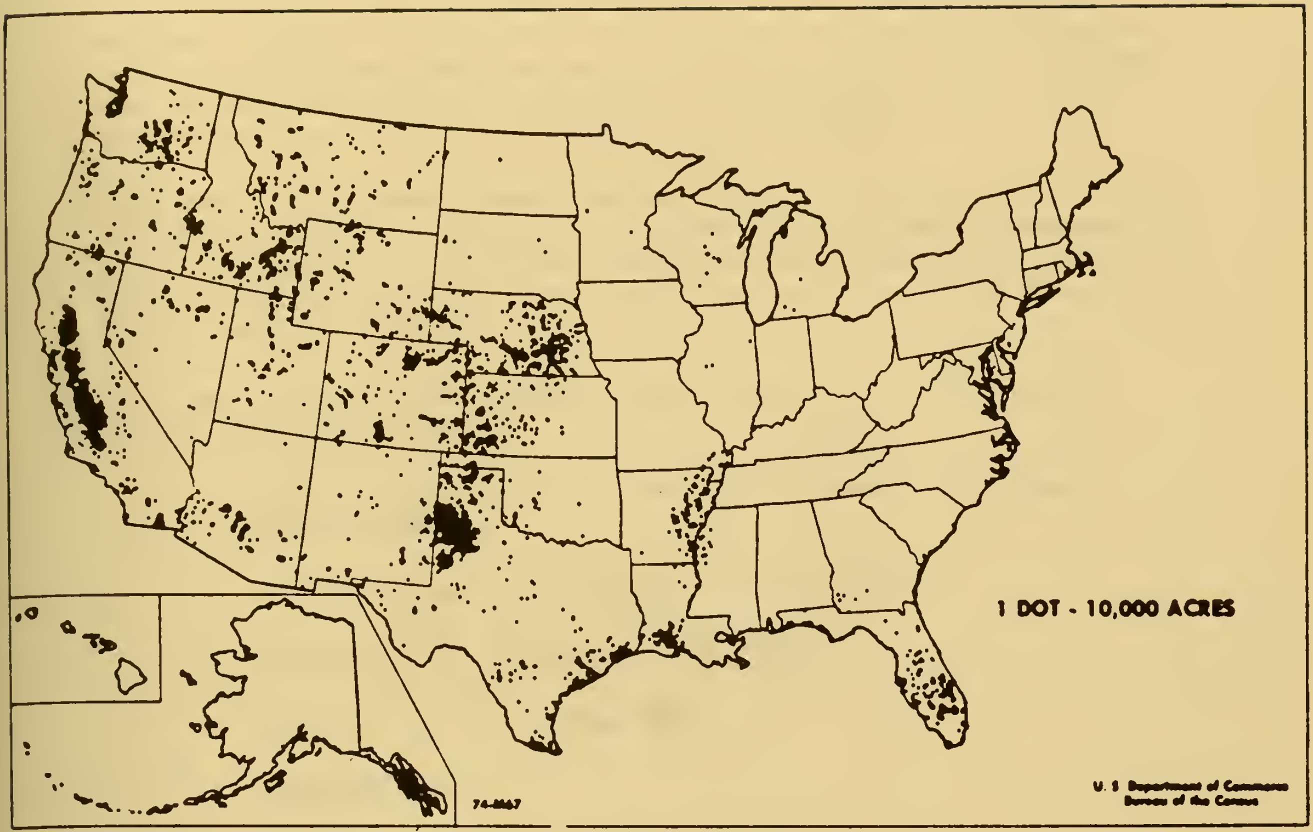


Figure 5C-4.--Location of irrigated land, 1974.

Appendix H:

Land Use and Land Ownership

Figure H-1 and tables H-1 and H-2 show the land use of federal and non-federal land for the United States and for the 17 Western States. The larger land use of non-federal lands is for cropland and "other" land which is primarily industrial and urban. The larger land use of federal lands is for rangeland.

This section discusses mainly how agricultural land use has been modified over the recent years and some of the effects produced by these changes. Through the years land has gone from crop to range, to urban use, to forest, and vice versa as can be seen in Figure H-2 and table H-3.

Land use changes of both temporal and spatial nature have been caused by factors such as:

1. the introduction of new and hybrid commercial crops, e.g., soybeans;
2. mechanical and technological improvements;
3. increased use of chemical fertilizers;
4. increased use of irrigation;
5. urbanization;
6. economic incentives and disincentives; and
7. desertification.

In the 1970's, land that had been taken out of production was put back into cultivation in the face of low food reserves, increased food demand (especially for exports), and increased economic constraints for the farmer so as to meet his rapidly rising costs.

Tables H-4 and H-5 show the decrease in the number of farms and the increase in the average acreage of farms. This is a consequence of the need for larger plots for the use of larger and more efficient machinery. The consolidation of small owner-operated farms into larger cooperative-owned agribusinesses resulted also in large, specialized, monocultural farms with an increased use of chemical fertilizers, pesticides, and herbicides, and with the necessary capital to install large irrigation systems like the center-pivot ones.

Urbanization has also affected land use changes by: (1) directly taking over agricultural land; (2) surrounding agricultural land; and (3) undermining the economic structure of agricultural land near expanding cities. This particular change is of special concern since in general it is the fertile, flat land with available water that is absorbed by urban sprawl. The Soil Conservation Service (SCS) estimates that about 80% of the available cropland in the U.S. is currently being cultivated. The other 25% can be converted to cultivation, but not all is of the same quality. Losses of productive acreage can have a severe impact on current and future agricultural activities. It has been estimated that for each acre removed by urbanization, another acre is surrounded and isolated as well, thus effectively removing twice the developed area. The SCS estimates that each year approximately five million acres disappear from the rural land reserve (Little 1979). This figure does not include the acreage under impending urban expansion.

The process works this way: First, land prices increase as speculators begin to recognize the development potential of an area. Then farmers, well aware of what is happening, become reluctant to invest in major, long-term improvements for their farms. This, in turn, may adversely affect the local farm support industries, which may be forced to relocate or go out of business. By the time early, scattered subdivisions appear, the local agricultural infrastructure may have already been severely weakened (Little 1979). This is a current and growing process in the Western States.

Land Ownership

Table H-6 shows the approximate acreage of land by ownership and by State.

Some states, especially Nevada, have a large portion of their land managed by the federal government./ See tables H-7, H-8 and H-9. In others, such as Texas, land is mostly privately owned. Arizona has the largest percentage in state ownership.

Changes in land use have led to some land ownership changes, such as the purchase of land by federal, state, and/or local governments for streets, highways, parks, government buildings or the sale or exchange of land by federal, state, and local governments to the private sector. The changes occuring in the last few years have generally not been large enough, in terms of acreage, to significantly alter the approximate figures presented in the tables.

Table H-1

OF THE APPROXIMATELY 772 MILLION ACRES IN NON–FEDERAL LAND IN THE 17 WESTERN STATES, THERE ARE APPROXIMATELY:

48 Million Acres of Irrigated Cropland

154 Million Acres of Dry Cropland

453 Million Acres of Range and Pastureland

70 Million Acres of Forestland

47 Million Acres of Other Land

Table H-2

Of the 370 million acres of federal land in the 17 Western States, there are approximately:

213 million acres of rangeland

143 million acres of forestland

28 million acres of other land

Table H-3

Major Uses of Land, 1974

(thousands of acres)

State	Cropland[1]	Grassland, Pasture and Range[2]	Forest Land[3]	Special Uses[4]	Other Land[5]
Great Plains Region	158,782	185,323	37,853	15,831	8,240
North Dakota	30,298	10,528	419	1,532	1,562
South Dakota	19,680	24,670	1,700	1,590	971
Nebraska	23,410	22,137	1,032	1,618	752
Kansas	31,625	15,950	1,363	2,210	1,196
Oklahoma	15,831	16,235	9,296	2,029	629
Texas	37,938	95,803	24,043	6,852	3,130
Mountain Region	42,801	307,445	119,852	43,778	33,992
Montana	16,021	49,465	19,899	4,633	3,158
Idaho	6,395	20,840	18,030	4,078	3,570
Wyoming	2,730	46,016	5,885	5,375	2,204
Colorado	10,959	29,274	19,387	3,238	3,552
New Mexico	2,302	50,525	17,256	5,325	2,295
Arizona	1,645	40,941	17,420	8,709	3,872
Utah	1,996	23,711	14,720	5,185	6,929
Nevada	753	46,673	7,255	7,235	8,412
Pacific Region	24,786	53,761	89,747	24,284	11,655
Washington	8,367	6,679	20,534	5,337	1,688
Oregon	5,276	23,172	29,387	2,655	1,067
California	11,143	23,910	39,826	15,292	8,900

Table H-3 con't.

1. Total acreage in the crop rotation.
2. Grassland and other non-forested pasture, excluding cropland used only for pasture.
3. Forest land, excluding reserved forest land and some unreserved areas duplicated in parks and other special uses of land.
4. Urban, transportation, recreational, etc.
5. Miscellaneous areas with low agricultural use value, such as marshes, open swamps, bare rock areas, deserts, and tundra.

Source: H. Thomas Frey, Major Uses of Land in the United States, 1974. Washington: USDA, November 1979.

Table H-4

Farm Population

(Thousands)

Region	1940	1970
Great Plains	4830	1511
Mountain	1118	445
Pacific	1269	501

Source: U.S. Dept. of Agriculture; Economics, Statistics, and Cooperative Service, Farm Population Estimates, 1910 - 1970 (Statistical Bulletin, No. 523)

Table H-5

Farms: Number, Acreage, and Value, by States: 1964 and 1974

Region	Number of Farms in Thousands		Average Acreage per Farm		Value of Farm Products Sold ($ millions)	
	1964	1974	1964	1974	1964	1974
Great Plains	565	477	644	782	6,534	18,111
Mountain	134	112	2,000	2,259	2,537	6,820
Pacific	167	124	458	551	4,564	10,083

Source: U.S. Bureau of the Census, Statistical Abstract of the U.S., 1978

Table H-6

Land Ownership by State

	Arizona	California	Colorado	Idaho	Kansas	Montana
Federal	51,060,000	44,047,518	23,649,157	33,334,522	754,410	37,987,409
State	8,857,000	3,255,515	3,086,164	2,594,837	111,766	5,321,309
Private	12,771,100	52,500,246	42,816,588	16,849,806	51,644,824	50,859,609
Other		1,760,510	293,439	119,081		

	Nebraska	Nevada	New Mexico	No. Dakota	Oklahoma	Oregon
Federal	734,237	61,617,277	32,912,078	3,167,773		32,315,826
State	2,447,456	141,491	9,217,070	3,163,552	No Figures Available	1,539,687
Private	45,277,936	8,986,832	35,637,251	38,894,275		27,837,531
Other	489,491					554,287

	So. Dakota	Texas	Utah	Washington	Wyoming
Federal	8,229,150	3,195,599	37,239,000	13,817,628	31,419,803
State	3,435,373	892,493	3,785,296	3,733,319	4,439,940
Private	37,645,557	164,129,508	11,356,354	22,168,694	26,544,097
Other			160,350	2,885,159	

Note: Indian lands held in trust are included in "Federal."
"Other" includes primarily city- and county-owned land.
If no "Other" category is listed, figures are included in "Private."

Source: Private communications from each State government.

Table H-7

Federally Owned Land

Region	Total Land (1000 acres)	Percent Owned by Federal Government
Great Plains	407,184	3.0
Mountain	548,448	49.1
Pacific	204,500	44.5

Source: U.S. General Services Administration, Inventory Report on Real Property Owned by the United States Throughout the World, 1977

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table H-8

Ownership of Rangelands in the Seventeen Western States, 1977

	Federal Lands Administered				
	Total	Bureau of Land Management	Forest Service	Other Federal	Non-Federal Lands
Great Plains	5,255.4	313.3	2,768.9	2,173.2	171,885.9
North Dakota	1,454.0	65.1	1,105.6	283.3	10,842.0
South Dakota	1,617.7	235.1	1,012.1	370.5	21,775.1
Nebraska	453.0	4.0	310.5	138.5	23,821.4
Kansas	223.2	1.0	107.9	114.3	16,055.1
Oklahoma	194.2	8.1	66.6	119.5	9,106.8
Texas	1,313.3	0	166.2	1,147.1	90,285.5
Rocky Mountains	167,410.6	123,293.6	27,231.7	16,885.3	164,811.3
Montana	10,995.5	7,308.0	2,926.8	760.7	42,338.6
Idaho	15,642.3	11,519.7	3,896.5	226.1	7,955.7
Wyoming	20,424.7	16,683.9	3,575.6	165.1	26,471.6
Nevada	52,592.8	44,389.3	3,987.5	4,216.0	4,295.0
Utah	23,056.3	16,689.9	3,047.3	3,319.1	6,734.4
Colorado	8,684.6	5,032.8	3,376.3	275.5	19,137.1
Arizona	20,903.0	10,728.1	5,027.7	5,147.2	24,264.8
New Mexico	15,11.4	10,941.9	1,394.0	2,775.5	33,614.1

Table H-8 con't.

Pacific Coast	40,146.9	25,907.5	6,891.3	7,348.1	33,110.5
Washington	1,667.6	265.5	647.9	754.2	6,227.4
Oregon	13,135.8	10,970.0	1,823.1	342.7	9,186.9
California	25,343.5	14,672.0	4,420.3	6,251.2	17,696.2
Totals	212,812.9	149,514.4	36,891.9	26,406.6	369,807.7

Table H-9

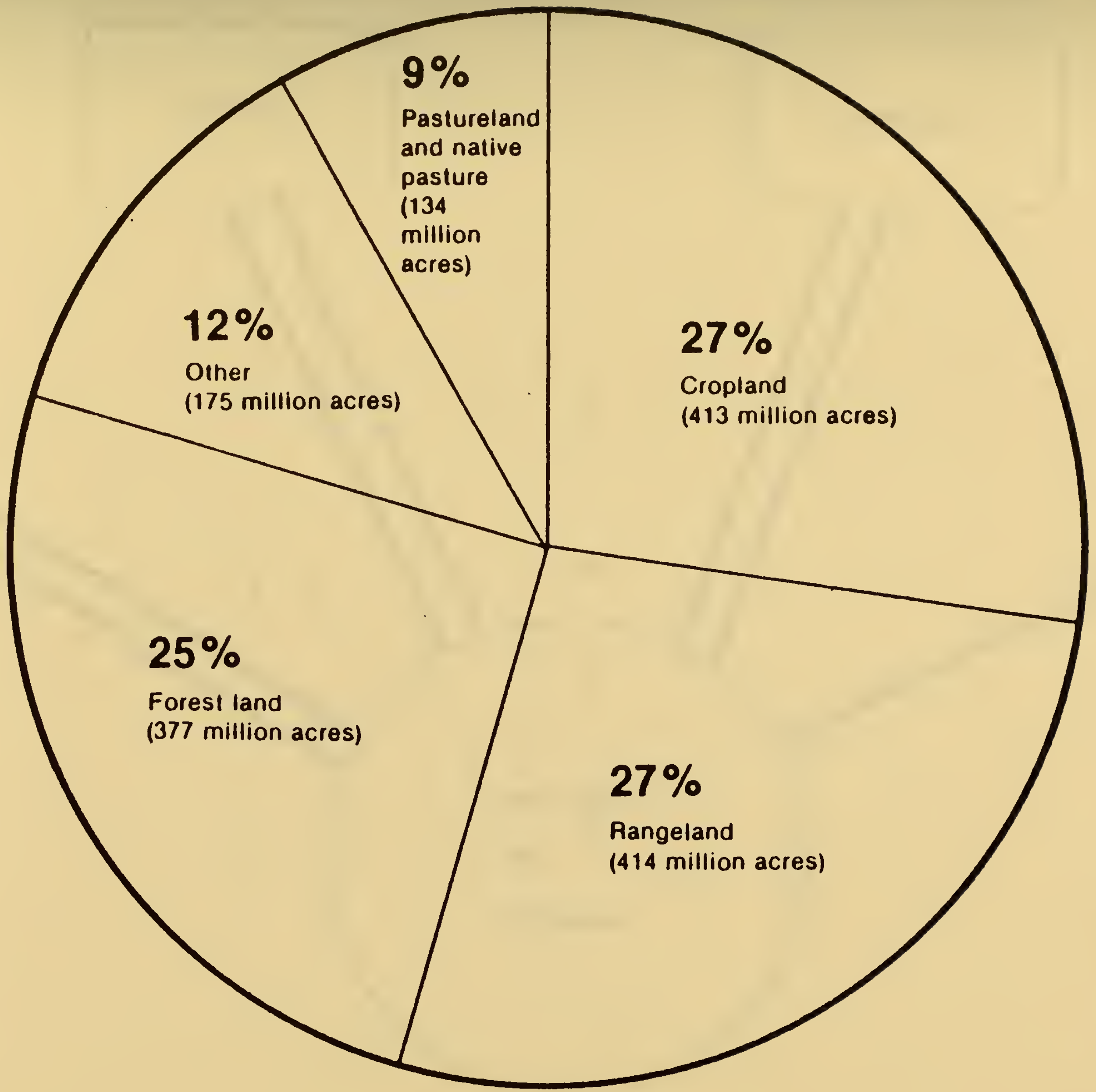
Lands Under Jurisdiction of the Bureau of Indian Affairs as of September 30, 1978

(acres)

Ownership	
Tribal	41,678,875
Individually Owned	10,110,375
Total Trust	51,789,250
Federally Owned	460,877
Total	52,250,127
Land Use	
Open Grazing	33,051,047
Commercial Timber	5,503,458
Non-Commercial Timber	7,452,904
Dry Farming	1,653,712
Irrigation Projects	841,777
Private Irrigation	183,753
Wild Land except Timber	3,478,497
Other Non-Agricultural Uses	382,960

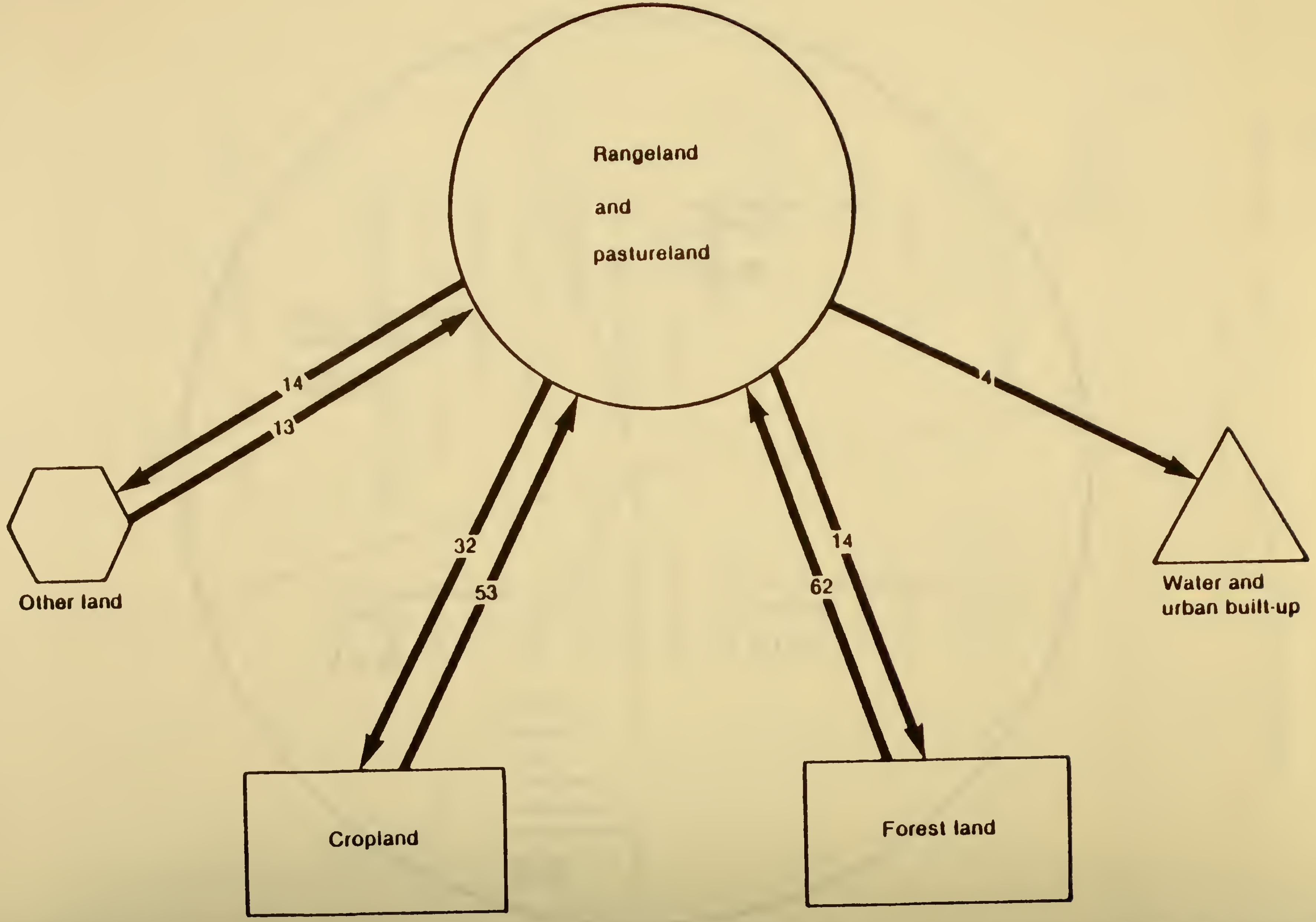
Source: Bureau of Indian Affairs

Figure H-1



Use of nonfederal land in the United States and the Caribbean, 1977. Source: USDA, RCA, 1980.

Figure H-2



Rangeland and pastureland conversions, 1967 to 1975 (millions of acres). (Potential Cropland Study 1977) Source: USDA, RCA, 1980.

Appendix I: Western States' Statements on Desertification

Some Western states, realizing that desertification is a problem within their borders, are formulating statements on desertification. California's statement is included here as an example of such an assessment. Following that, sections of a Water Resources Council (WRC) assessment present a state-by-state summary of water resources issues and management policy.

State of California

Department of Conservation

1416 9th St., Rm. 1320

Sacramento, California 95814

Indicators of Desertification in California

February 1980

INDICATORS OF DESERTIFICATION IN CALIFORNIA

Introduction

California presently exhibits some significant parallels with other parts of the world affected by the process of desertification. Hare (1977) has shown that most of California shares climatic similarities with other parts of the world where desertification problems are occurring. Also, a large portion of California is considered to be affected by this process to a slight or moderate degree, with severe problems occurring in some desert areas (Dregne, 1978). Supporting information is provided by the California Departments of Conservation, Forestry, and Water Resources, in this report. Maps and tables indicating the general location and areal extent of various problems are presented in the report. However, these maps and tables do not provide information on the severity of these problems. Most of these data were derived from responses of Resource Conservation Districts (RCD's) to a Department of Conservation questionnaire. (Department of Conservation, 1979). Where specific information on severity is known, comments will be made in the text or in the summary at the end of the report.

California's Desertification Problems

Dregne (1978) has defined desertification as the process of the impoverishment of terrestrial ecosystems under the impact of man, while Hare (1977) restricts the definition of the process to the degradation of grassland, scrub, or savanna ecosystems. In California, where a large portion of the State's natural environment is comprised of grassland, scrub, or savanna ecosystems, the indicators of such impoverishment are:

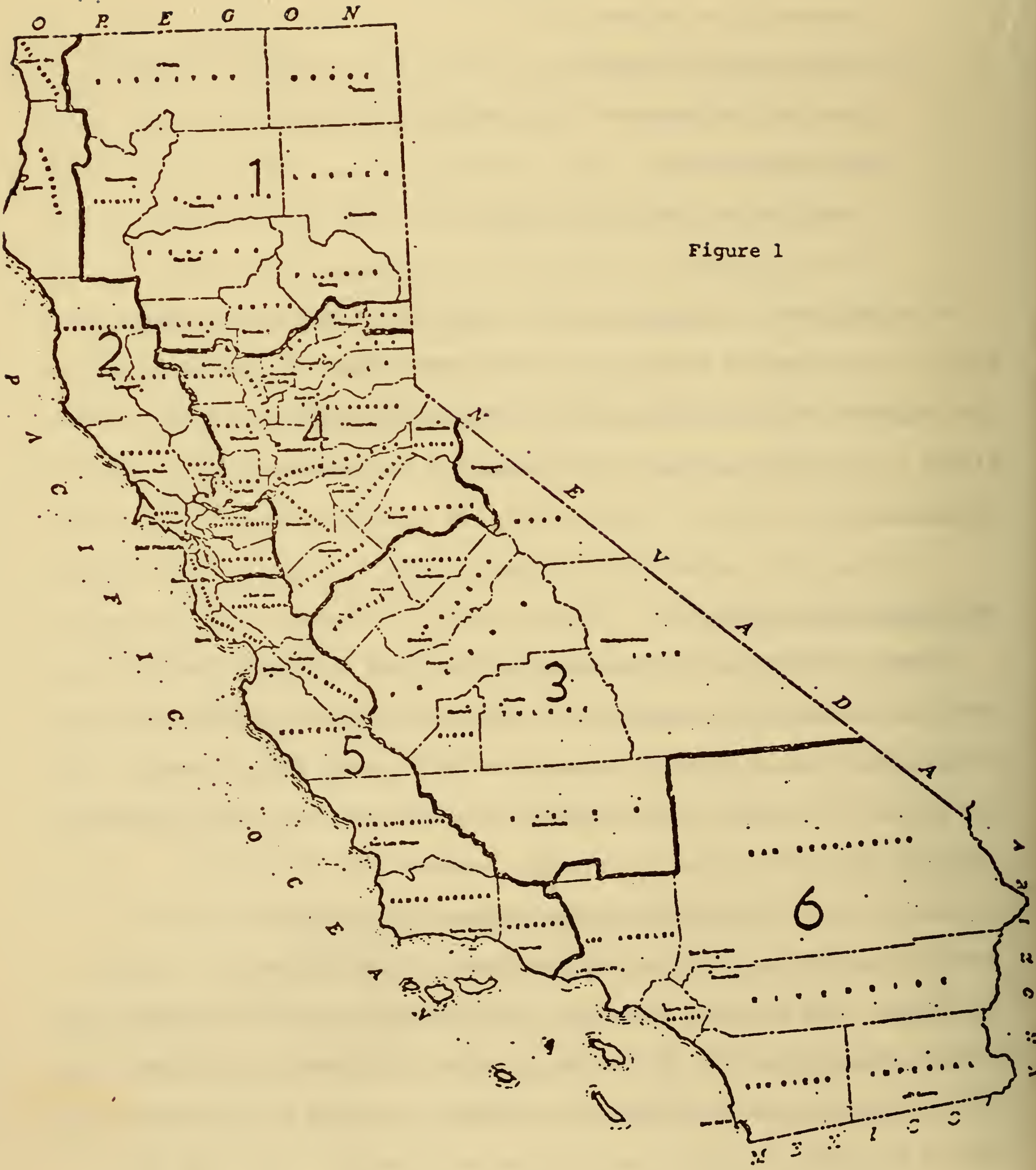
- accelerated water erosion;
- accelerated wind erosion;
- poor soil drainage and soil salinity increases;
- soil compaction;
- invasions of undesirable plants;

A description of each problem, its location, and severity follows. Most of the tables and figures are divided into regions of California that represent U.S. Soil Conservation Service Administrative Areas. Figure 1 shows the location of these areas and the counties they encompass.

Accelerated Water Erosion

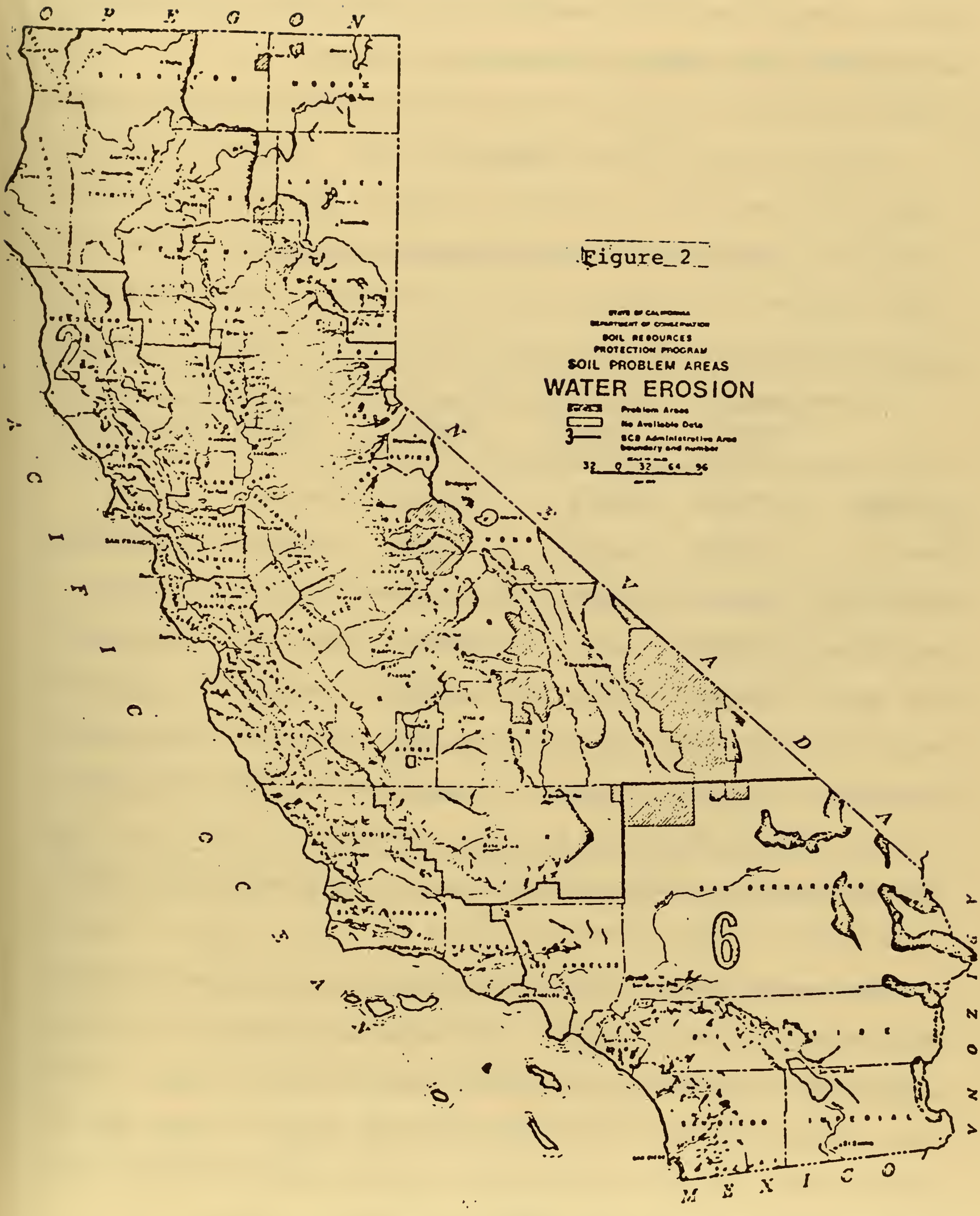
Water Erosion occurs in most areas of the State (Figure 2, Table 1). However, it is a serious problem on sloping croplands surrounding the Central Valley and in certain areas of the north coast, central coast, and southern California. The problem is largely associated with orchard, vineyard, and nonirrigated grain crops. Serious soil erosion has occurred on many Southern California brushlands cleared and planted in avocados. Slopes as steep as 60% have been utilized for these plantings. Most observed areas have had no terracing or other erosion control measures applied. The principal areas of concern are northern San Diego County, southwestern Riverside County, and the steep slopes facing the ocean in Ventura and Santa Barbara Counties. Soil loss from

Figure 1



SCS ADMINISTRATIVE AREAS

Figure 2


STATE OF CALIFORNIA
DEPARTMENT OF CONSERVATION
SOIL RESOURCES
PROTECTION PROGRAM
SOIL PROBLEM AREAS
WATER EROSION
Problem Areas
No Available Data
SCS Administrative Area boundary and number
32 0 32 64 96
O R E G O N
N E V A D A
A R I Z O N A
M E X I C O
P A C I F I C O C E A N
2
6
SAN FRANCISCO
SAN BERNARDINO

many orchards has exceeded 200 tons per acre but estimates have not been made of the total severity of the problem. It occurs on about one million acres of steep land, primarily on soils originally formed under oak woodlands where chaparral has subsequently invaded.

Table 1

Water Erosion Problems Related to Land Use*

	Cropland (acres)	Pastureland (acres)	Rangeland (acres)	Forestland (acres)	Urban (acres)
Statewide	1,975,000	190,000	6,200,000	834,000	341,000
Area I	25,000	28,000	610,000	95,000	3,000
Area II	134,000	44,000	961,000	115,000	1,000
Area III	517,000	-0-	1,869,000	336,000	60,000
Area IV	319,000	37,000	889,000	93,000	95,000
Area V	787,000	75,000	1,046,000	185,000	114,000
Area VI	191,000	7,000	824,000	10,000	68,000

*Source: Department of Conservation Inventory (RCD Questionnaire, 1978).

Water erosion is also a chronic and sometimes acute problem on the rangelands of the State (Table 1). The problem is related to congregation of cattle leading to overutilized and compacted areas. Also, the problem of adjusting herd sizes by speculators who lease out grazing rights, and fail to exercise the soil stewardship a resident landowner might be expected to follow, compounds the problem.

Soil erosion on rangeland from overutilization is common in the Coast Ranges. The problem is not as serious as it was 50 and 100 years ago as most ranchers practice better range management than in the past. However, much of the rangeland on the foothills and alluvial fans of the western flank of the Sierra Nevada were also severely overutilized during the 1975-1977 drought. This resulted in extensive erosion in the area which also is indicated in Figure 2 and Table 1. The areas of the state that are most consistently overgrazed are shown in Figure 3. Few precise data exist on rates of erosion from rangeland over time. The most recent estimate was based on the 1977 Soil Conservation Service National Erosion Inventory, which indicated that average annual rates of sheet and rill erosion on California's rangelands were 6.2 tons/acre/year.

Accelerated Wind Erosion

For wind erosion to occur, requisite combination of soil types and climate factors must exist. Kimberlin and others (1977) found that almost five million acres of soils highly susceptible to wind erosion (sands, loamy sands, sandy loams, and mucks) are found on California's private lands alone. Although the wind erosion equation for predicting soil loss (Woodruff and Siddoway, 1965) has not been refined for California, our desert areas are estimated to have some of the highest climatic factors for potential wind erosion found anywhere in the United States (Soil Conservation Service, 1965). Further, while mean annual windspeeds are often low in California, a recent analysis of weather station data by the Department of Water Resources (1978) indicates that extreme winds and windstorms (which increase wind erosion) are not unusual climatic events.

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF CONSERVATION
DIVISION OF FORESTRY

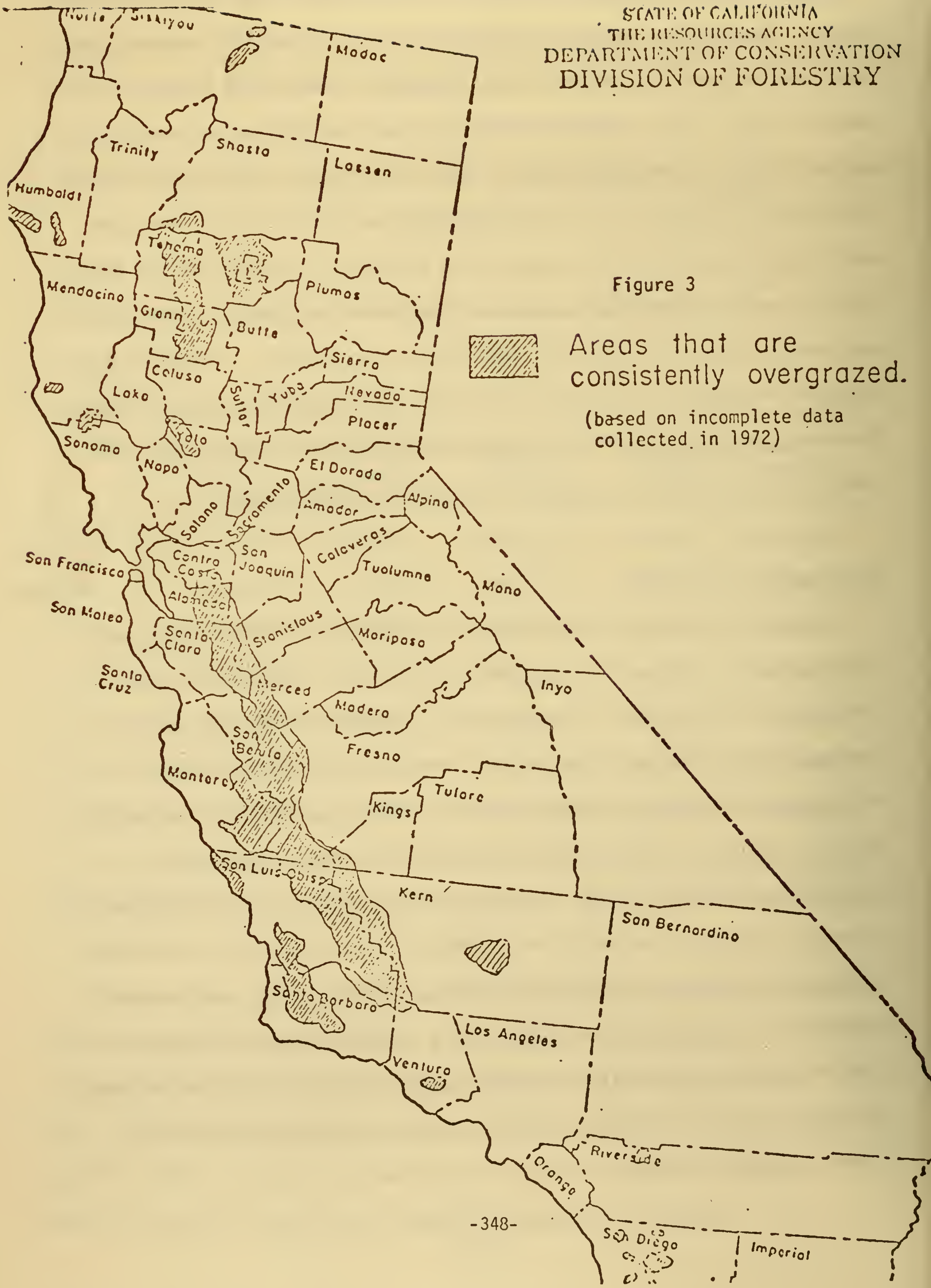


Figure 3

▨ Areas that are consistently overgrazed.

(based on incomplete data collected in 1972)

According to the Department of Conservation (1979) assessment, wind erosion affects large areas of the state as is illustrated in Figure 4 Table 2. In general, few soil conservation measures are employed to control wind erosion on cropland and excessive discing often destroys soil structure. There are also fine-sandy soils, easily eroded by wind, located in the Antelope and San Joaquin Valleys, as well as highly erodible peats found in the Sacramento-San Joaquin Rivers Delta. Overutilization of rangeland during the 1975-1979 drought coupled with a severe windstorm, led to the removal of an average of 167 tons/acre of soil over a 230 square mile area in the foothills flanking the east side of the Sierra Nevada (Wilshire, 1978). A different problem exists on the east side of the Sierra Nevada where surface water diversions and groundwater pumping are dessicating the area and accelerating the drying up of pluvial lakes, which has caused large dust storms and may be causing changes in vegetation (Mono Lake Task Force, 1979, and Reinking et al, 1975).

Soil Drainage and Soil Salinity

The Department of Conservation (1979) has estimated that drainage and salinity problems in California are extensive (Tables 3 and 4; Figures 5 and 6).

However, the critical problem areas have been defined by the San Joaquin Valley Interagency Drainage Program (1979) and are found along the western rim of the San Joaquin Valley. High, brackish water tables now underlying about 400,000 acres (160,000 hecates) of irrigated farmland in the San Joaquin Valley pose an increasingly serious threat to productivity. Ultimately, more than a million acres will be similarly

Figure 4

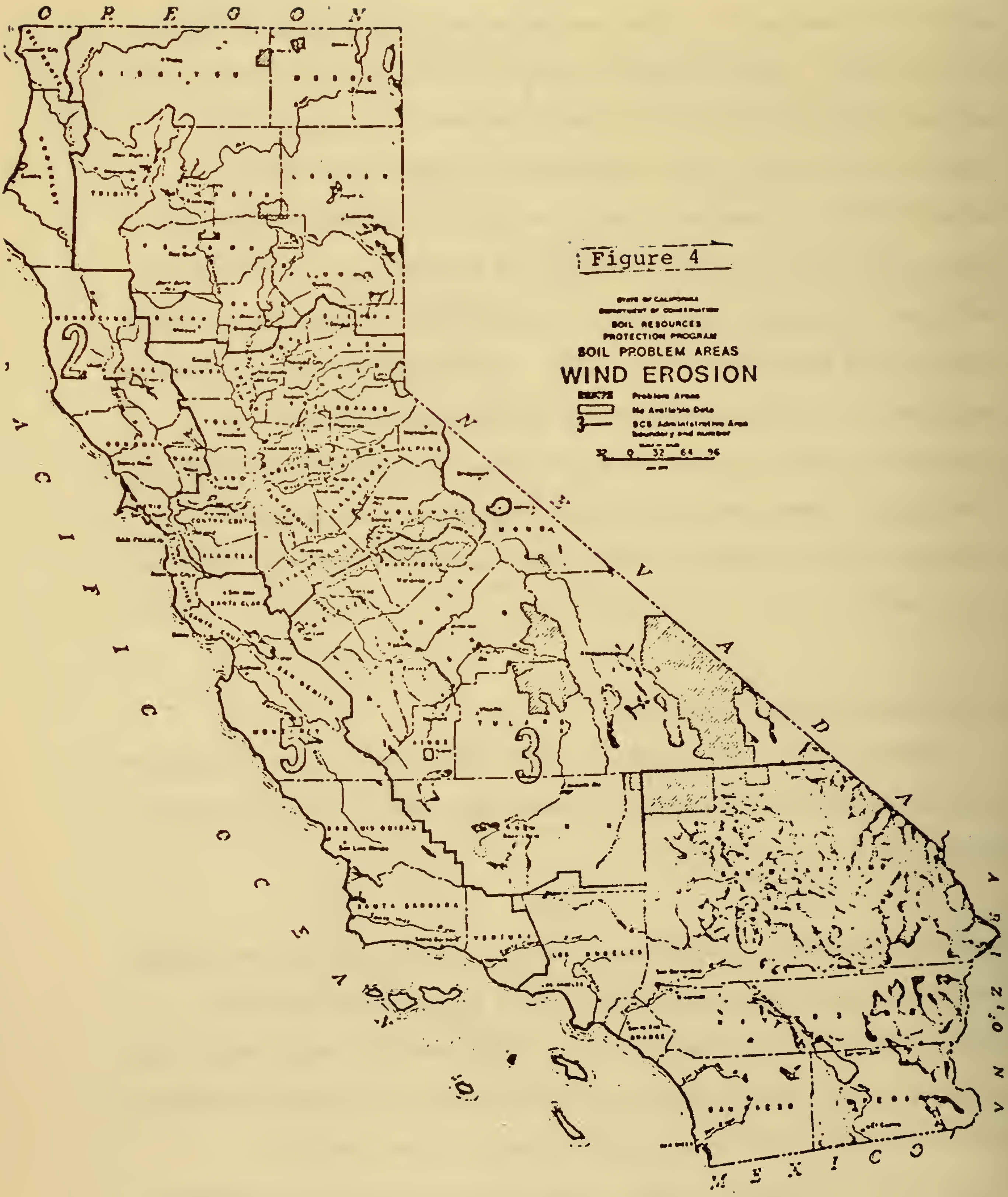

STATE OF CALIFORNIA
DEPARTMENT OF CONSERVATION
SOIL RESOURCES
PROTECTION PROGRAM
SOIL PROBLEM AREAS
WIND EROSION
Problem Areas
No Available Data
SCS Administrative Area boundary and number
32 0 32 64 96
O R E G O N
N E V A D A
A R I Z O N A
M E X I C O
P A C I F I C O C E A N
2
3
5
SANTA BARBARA
LOS ANGELES
SANTA CLARA
CONTRA COSTA
SAN FRANCISCO

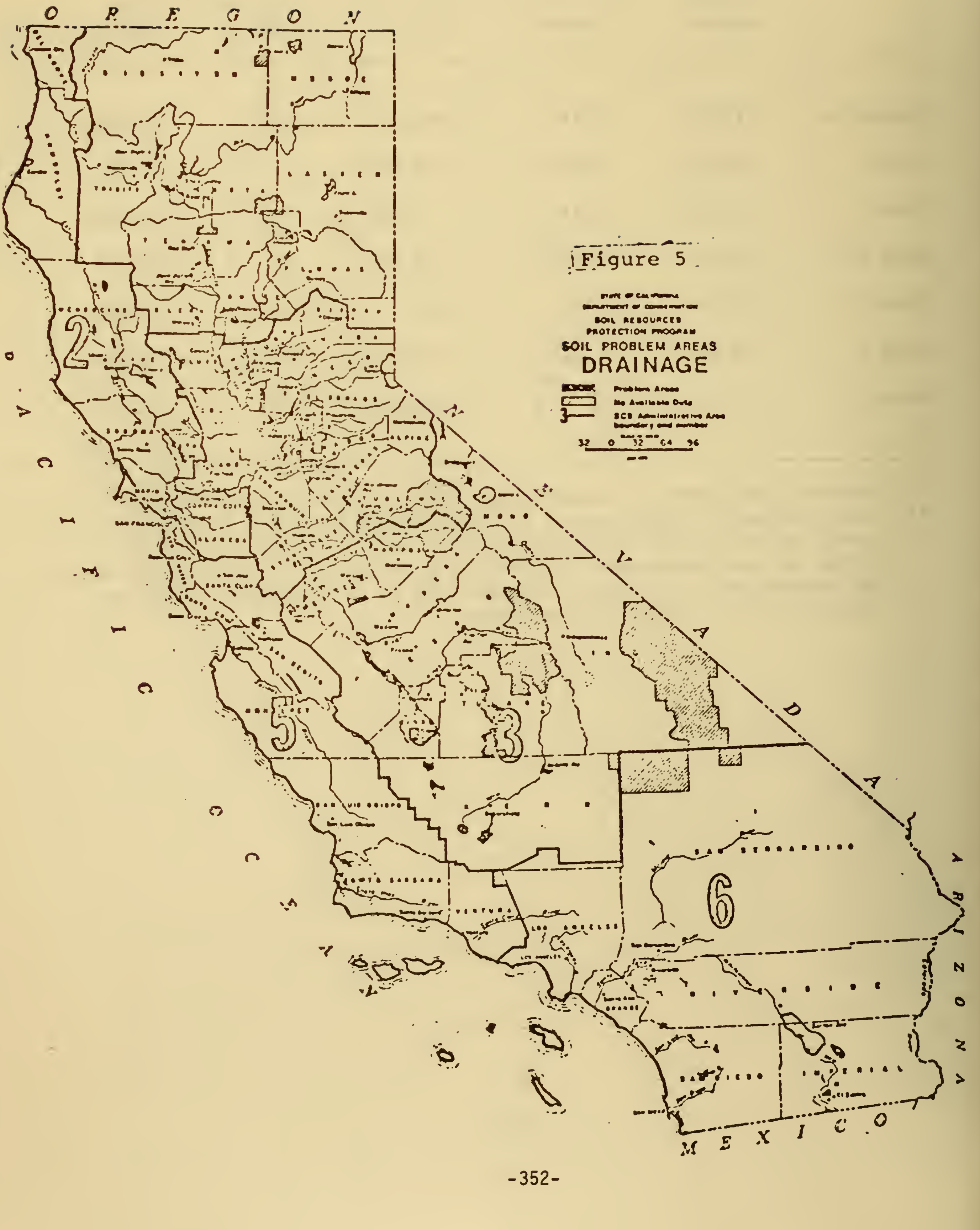
Table 2

Wind Erosion Problems Related to Land Use*

	Cropland (acres)	Pastureland (acres)	Rangeland** (acres)	Forestland (acres)	Urban (acres)
Statewide	700,000	66,000	7,583,200	21,000	74,000
Area I	80,000	3,000	164,000	-0-	-0-
Area II	17,000	10,000	5,000	-0-	1,000
Area III	126,000	16,000	218,000	-0-	30,000
Area IV	272,000	-0-	-0-	-0-	1,000
Area V	57,000	37,000	37,000	21,000	10,000
Area IV	157,000	-0-	7,159,200	-0-	32,000

* Source: Department of Conservation Inventory (RCD Questionnaire.)

** This includes a large area of the Mojave Desert in San Bernardino County which the RCD considers seasonal range. However, the U.S. Bureau of Land Management indicates the majority of this land is used for recreation, more properly classified in an additional land use category to that shown in the Table.

OREGON
NEVADA
ARIZONA
MEXICO
PACIFIC OCEAN
2
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STATE OF CALIFORNIA
DEPARTMENT OF CONSERVATION
SOIL RESOURCES
PROTECTION PROGRAM
SOIL PROBLEM AREAS
DRAINAGE
Problem Areas
No Available Data
SCS Administrative Area
boundary and number
32 0 32 64 96

Figure 5

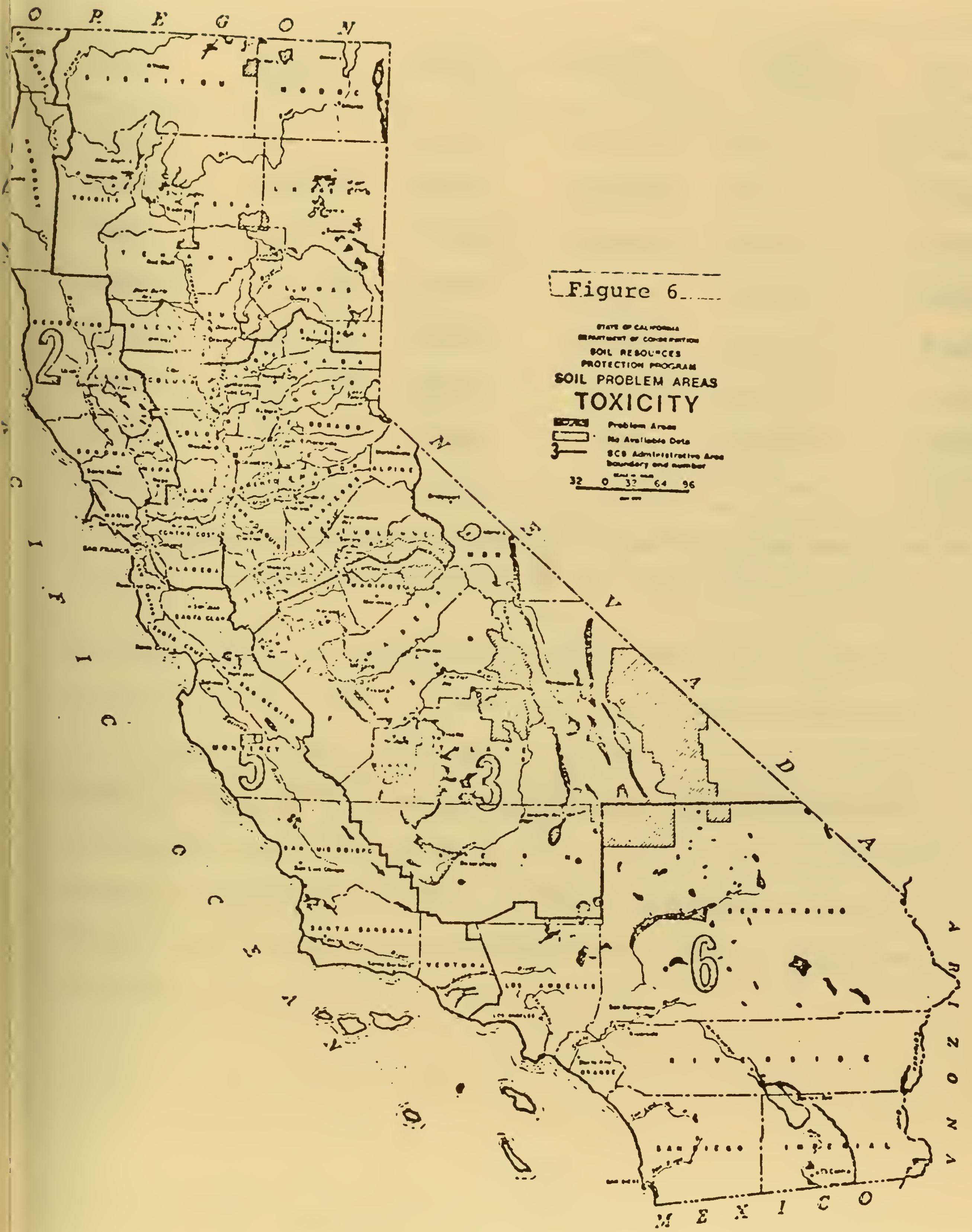


Figure 6

STATE OF CALIFORNIA
DEPARTMENT OF CONSERVATION
SOIL RESOURCES
PROTECTION PROGRAM
SOIL PROBLEM AREAS
TOXICITY
Problem Areas
No Available Data
3
SCS Administrative Area Boundary and number
32 0 32 64 96
OREGON
NEVADA
ARIZONA
MEXICO
PACIFIC OCEAN
2
3
5
6
COLUSA
ALPINE
SAN FRANCISCO
SANTA BARBARA
VENTURA
LOS ANGELES
SAN BERNARDINO
RIVERSIDE
SAN DIEGO
IMPERIAL

Table 3

Drainage Problems Related to Land Use*

	Cropland (acres)	Pastureland (acres)	Rangeland (acres)	Forestland (acres)	Urban (acres)
Statewide	1,284,000	412,000	125,000	-0-	34,000
Area I	46,000	104,000	36,000	-0-	1,000
Area II	33,000	16,000	-0-	-0-	-0-
Area III	534,000	88,000	9,000	-0-	4,000
Area IV	371,000	199,000	60,000	-0-	20,000
Area V	36,000	4,000	11,000	-0-	3,000
Area VI	264,000	-0-	10,000	-0-	5,000

*Source: Department of Conservation Inventory (RCD Questionnaire)

Table 4

Toxic Salt Problems in Relation to Land Use*

	Cropland (acres)	Pastureland (acres)	Rangeland (acres)	Forestland (acres)	Urban (acres)
Statewide	1,649,000	129,000	382,000	-0-	32,000
Area I	46,000	23,000	124,000	-0-	-0-
Area II	8,000	3,000	-0-	-0-	1,000
Area III	1,000,000	79,000	169,000	-0-	4,000
Area IV	97,000	2,000	2,000	-0-	-0-
Area V	137,000	19,000	-0-	-0-	9,000
Area VI	362,000	2,000	86,000	-0-	18,000

*Source: Department of Conservation Inventory (RCD Questionnaire)

affected. Loss of the productive capacity of these lands would be a serious loss to the people who farm them, to the economic community of the San Joaquin Valley, to the State of California, and to the United States. To prevent this loss, a comprehensive system is required to manage and dispose of the saline effluent of on-farm subsurface drainage systems. The general location of drainage problem areas is shown in Figure 7, and the magnitude and severity of the problem is demonstrated in Table 5.

Table 5

Expected Drainage Problem Acreage and Drain Water Quantities, 1985-2085*

Year	Maximum Area Requiring Drainage (acres)	Area Drained 1/ (acres)	Quantities (acre-feet)
1985	294,000	56,000	57,000
1995	462,000	346,000	310,000
2005	586,000	507,000	424,000
2015	693,000	623,000	484,000
2025	792,000	720,000	518,000
2035	867,000	807,000	566,000
2045	925,000	876,000	575,000
2085	1,040,000	1,023,000	668,000

1/ "Area drained" never equals "area requiring drainage" because it was assumed that due to individual farm practices and economies, some farmers would never install drainage even though it would be to their economic advantage to do so.

* From "Agricultural Drainage and Salt Management in the San Joaquin Valley"; San Joaquin Valley Interagency Drainage Program, 1979.

FIGURE 7 . DRAINAGE PROGRAM STUDY AREAS SAN JOAQUIN VALLEY

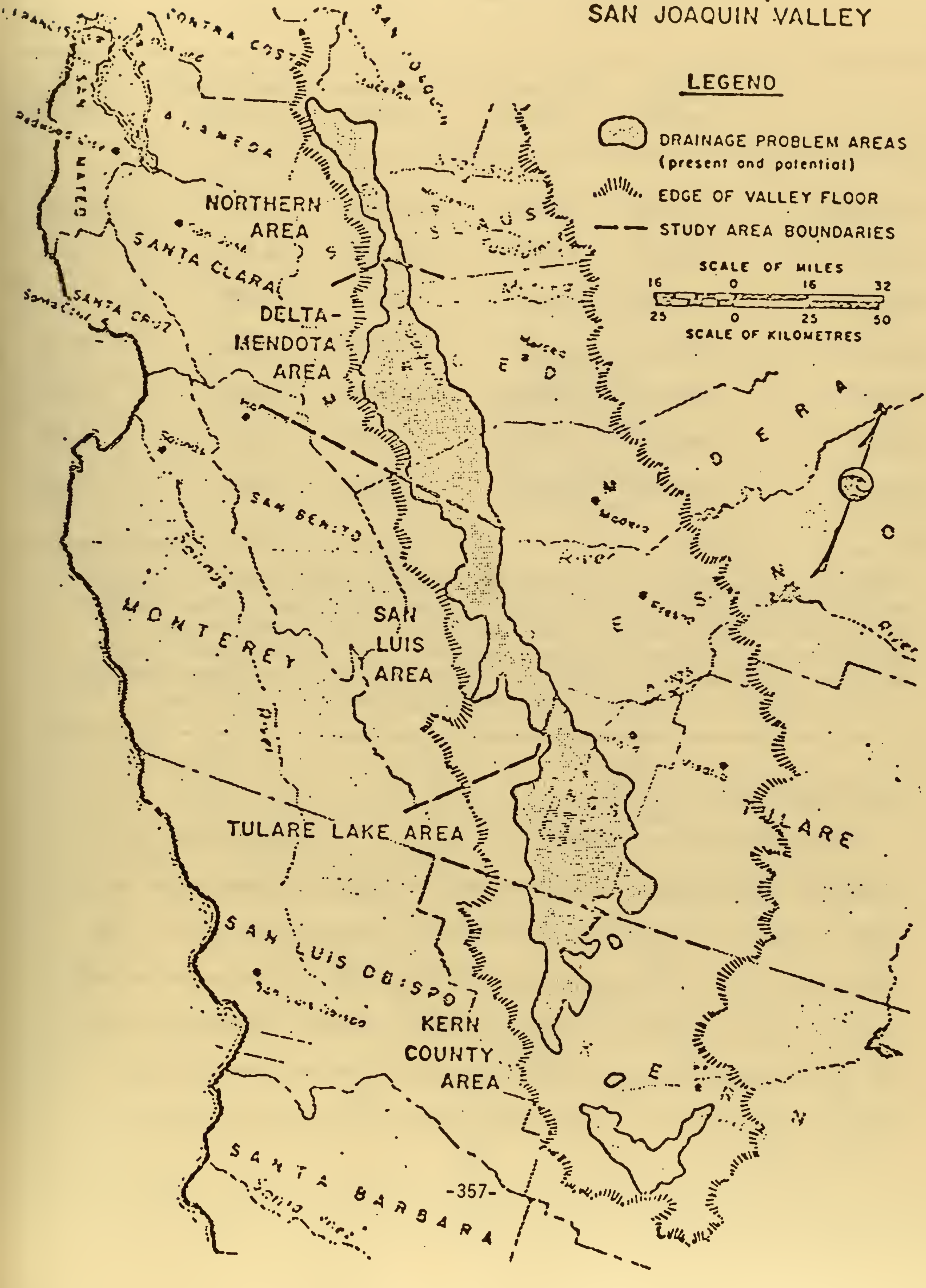


Table 6

Compaction Problems in California Soils*

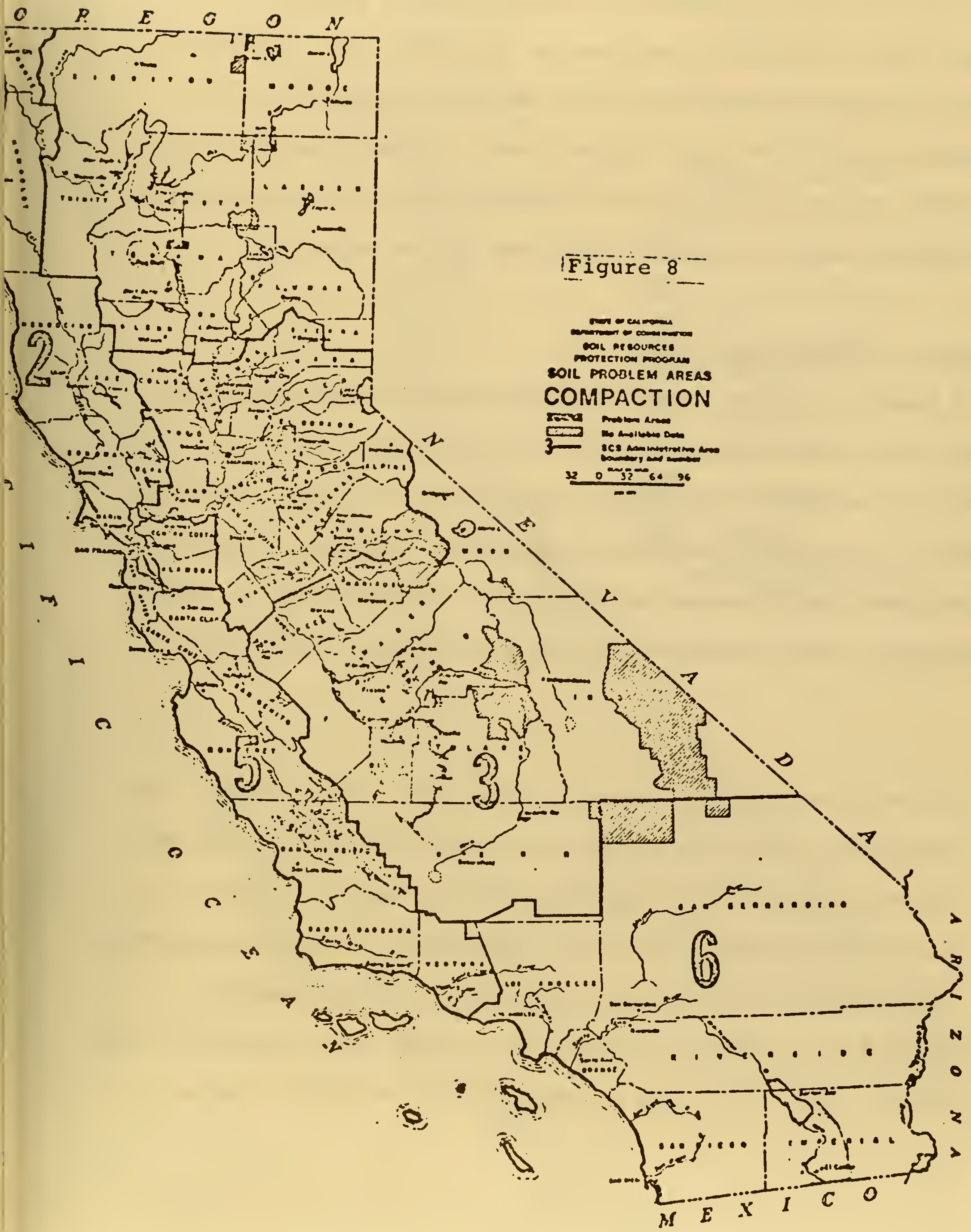
	Cropland (acres)	Pastureland (acres)	Rangeland (acres)	Forestland** (acres)	Urban (acres)
Statewide	2,413,000	143,000	425,000	31,800	25,000
Area I	56,000	14,000	376,000	16,500	-0-
Area II	14,000	-0-	-0-	22,100	-0-
Area III	874,000	84,000	27,000	1,000	3,000
Area IV	680,000	44,000	15,000	2,200	20,000
Area V	442,000	-0-	3,500	-0-	1,000
Area VI	347,000	1,000	4,000	-0-	1,000

*Source: Department of Conservation Inventory (RCD Questionnaire.)
**Estimated from USFS and CDF data on percent of harvest areas compacted by tractors and the amount of land harvested using tractor logging techniques over the past 10 years. Source: U.S. Forest Service, 1977; Report on the findings of the Soil Compaction Study Task Force; Regions 5, 6, and Pacific Southwest Forest and Range Experiment Station.

Soil Compaction

Soil compaction is a widespread problem in California, affecting croplands, pasturelands, rangelands and forestlands in some degree as is shown in Figure 8 and Table 6 (Department of Conservation, 1979). The susceptibility of soil to compaction is related to soil moisture content, texture, structure, and the amount of organic matter. Compaction of the soil will lead to lowered infiltration rates, lowered water holding capacity and accelerated runoff thus increasing the erosion hazard.

Figure 8


STATE OF CALIFORNIA
DEPARTMENT OF CONSERVATION
SOIL RESOURCES
PROTECTION PROGRAM
SOIL PROBLEM AREAS
COMPACTION
Problem Areas
No Available Data
SCS Administrative Area
Boundary and Number
32 0 32 64 96
OREGON
NEVADA
ARIZONA
MEXICO
PACIFIC OCEAN
2
3
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6

Roberton and Erickson (1978) have shown that compaction is more prevalent in soils containing less than 3% organic matter. Most of the cropland and rangeland soils in California's interior valleys and foothills have organic matter contents of less than 3%. Therefore, under the impact of agricultural use, we may conclude that many California soils are compacted somewhat over their natural state. The basic causes are heavy equipment use, particularly on moist cropland soils, and overutilization of rangeland, which is acute in areas where cattle congregate.

Invasions of Undesirable Plants

A number of problems exist with the invasion of undesirable plants, some of them quite serious, and others with considerable potential for becoming troublesome. The natural vegetation of California is shown in Figure 9. The greatest invasion was related to the introduction of Mediterranean annual grasses and almost total replacement of the native perennials. Specific problems of plant invasions are listed below.

(1) The chaparral and brush invasions of grasslands, oak woodlands, and coniferous forest of which there are two basic causes. First, was the heavy grazing in the Spanish era and the early period of California statehood. Second was the attempt to totally exclude fire which lead to further expansion and perpetuation of chaparral.

(2) Medusa head and barbed goatgrass were invading many rangelands in the northern part of the State during the 1950's and 60's. They are a

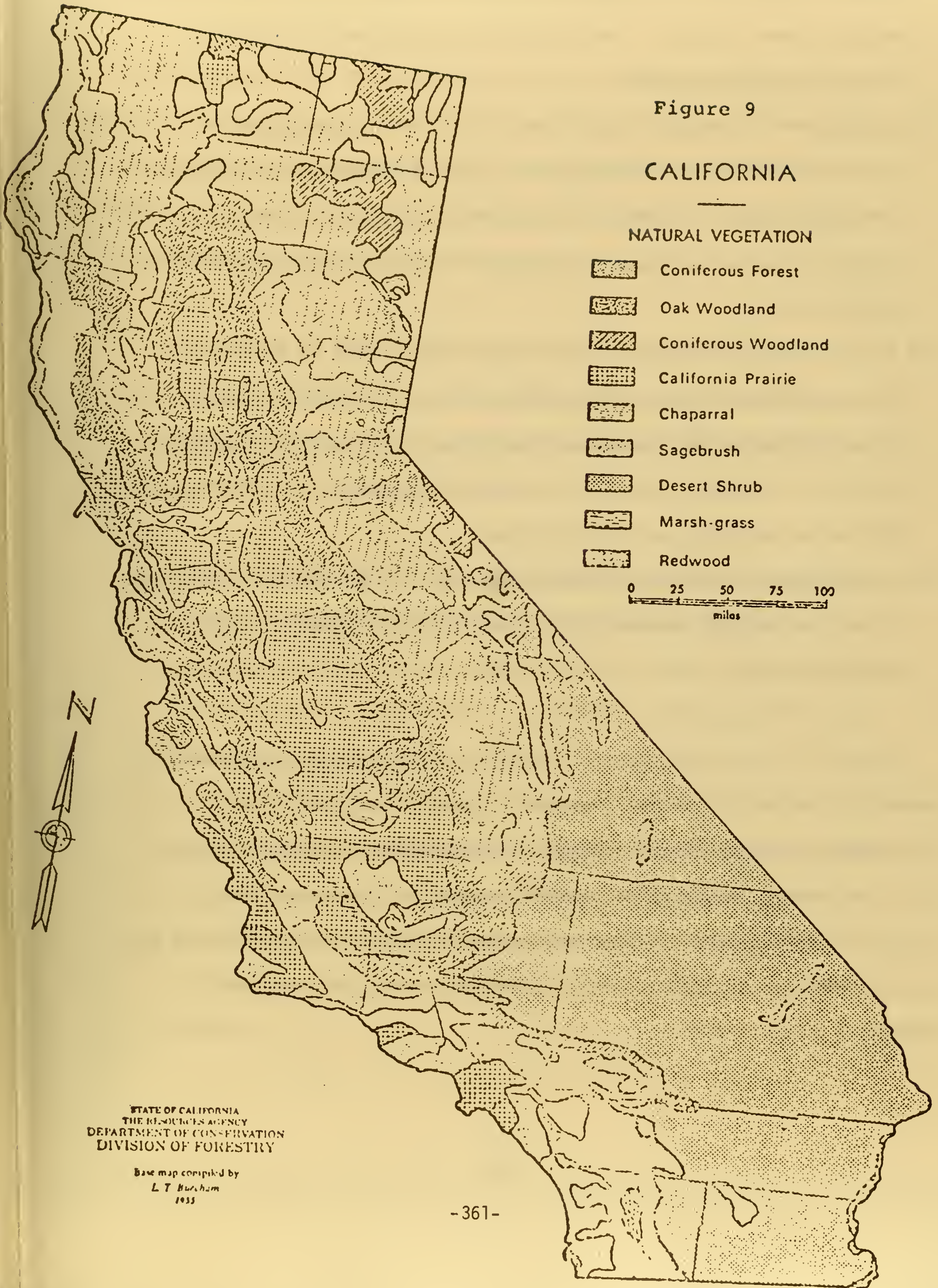

Figure 9

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF CONSERVATION
DIVISION OF FORESTRY

Base map compiled by
L. T. Burcham
1955

further degradation of vegetation quality over the existing cover of Mediterranean annuals. The problem has largely been reduced by better grazing management.

(3) Halogeton is a problem in the Great Basin and has been a minor problem in the sagebrush ranges of Lassen and Modoc Counties and in the Owens Valley. However, it can be controlled fairly well by improved grazing management and is not viewed as a major problem in California.

(4) Scotch broom is a problem in the lower timber belt of the central Sierra Nevada and also in the coastal areas of Mendocino County. It is an aggressive and tenacious competitor of even the native brush species. Control efforts in the past were based on 2, 4, 5-T which is now banned from use in California.

(5) Pampas grass is not yet a problem, but it is a concern in the coastal areas near Big Sur in the Control Coast and in Mendocino County coastal areas.

Whether or not these specific invasions or the whole replacement of perennial grasses by annuals indicates a general degradation of California's rangelands is a subject of controversy. However, we can note that during the period from 1968 through 1977 the condition of rangeland in California ranged from severe drought to excellent with an average condition of poor to fair (California Crop and Livestock Reporting Service, 1978).

SUMMARY AND CONCLUSIONS

It is evident that the processes associated with desertification are operating in California. However, it is difficult to assess the severity of the problem on a statewide basis. If we apply the criteria for estimating the degree of desertification as defined by Dregne (1979) we can reach the following general conclusions.

- The degree of desertification related to the drainage and salinity problem area shown in Figure 7 would be considered slight (crop yields reduced less than 10%). The trend is toward a worsening of this condition.

- The rangelands of the state would exhibit none to a moderate degree of desertification, but on the average could be considered moderate (fair range condition class, with moderate sheet erosion and some shallow gullies). Trends are difficult to determine at this time.

- Desert areas would be defined as severe (since range condition is generally poor, gullies are common, severe sheet erosion occurs and occasional blow-out areas exist. Many of these problems are influenced by heavy off-road vehicle use in the desert.

It is even more difficult to determine the economic costs of desertification in California. The only problem that has been analyzed from an economic perspective is the salinity and drainage problem in the San Joaquin Valley. Table 6 provides insight into the amount of drainage needed to prevent loss of agricultural production.

Recommendations to combat the drainage and salt management problem as proposed by the San Joaquin Valley Interagency Drainage Program (1979) are:

The IDP recommends a comprehensive drainage and salt management program for San Joaquin Valley. The IDP Recommended Plan proposes the following:

1. A drainage canal (the Valley Drain) along the San Joaquin Valley trough, discharging in Suisun Bay near Chipps Island.

2. A total of 64,300 acres (25 800 ha) of new or restored wetland wildlife habitat, of which 45,300 acres (18 200 ha) would be brackish marshes and 19,000 acres (7 600 ha) would be reservoirs or holding ponds. The marshes, supplied with drain water, would help to protect the wildlife resource of the Pacific Flyway. Six sites would be involved, five in the San Joaquin Valley and one on the south shore of Suisun Bay in Contra Costa County.

GROSS VALUE OF AGRICULTURAL OUTPUT*
MAINTAINABLE BY DRAINAGE
($ million)

	1985	1995	2005
North Area	2.1	4.4	7.2
Delta Mendota	16.4	111.8	123.5
San Luis	3.9	32.9	67.5
Tulare Lake	6.3	48.5	73.6
Kern County	2.5	26.6	49.5
Total	31.2	224.2	321.3

*From "Agricultural Drainage and Salt Management in the San Joaquin Valley; San Joaquin Valley Interagency Drainage Program," 1979.

3. Staged construction of drainage facilities. The existing 82-mile (132 kilometre) segment of the San Luis Drain, approximately in the middle of the proposed 290-mile (467 km) Valley Drain alignment, would serve as the Valley Drain's first segment. By 1985, an additional 26 miles (42 km) would be added to the southern end of the San Luis Drain. By 1991, the Drain would be extended northward to Suisun Bay. If future environmental studies indicate that drainage effluent from the southern part of the valley would cause no

unacceptable effects in the receiving waters, the Drain would be extended southward by the year 2000 to a point near the southern extremity of the valley trough.

Recommendations for financing and implementation include the following:

1. That responsibilities for financing project costs associated with implementation of the Recommended Plan be shared by the Federal and State Governments in these proportions: 58 percent Federal, 42 percent State.

2. That project costs allocated to agricultural drainage and water conservation be reimbursable and that costs allocated to the other two project purposes, marshes and water quality, be nonreimbursable. Costs allocated to the environmental quality (EQ) objective under the Principles and Standards of the National Water Resources Council would also be nonreimbursable.

3. That the Federal and State Governments contract with local entities meet their contractual commitments by collecting charges from: (a) those who, by irrigating, contribute to the drainage problem; and (b) those who discharge into facilities of the valleywide drainage system.

4. That costs allocated to water conservation be recouped by selling drain water for such purposes as power plant cooling.

5. That local entities contracting with the State and Federal Governments for drainage and disposal service meet their contractual commitments by levying per-unit fees on effluent discharged to collector facilities and by per-unit charges on irrigation water applied in both the drainage problem areas and the areas that contribute to the drainage problem. The recommended applied water charges are $1.00 per acre-foot in Federal areas and $2.00 per acre-foot in State areas. The recommended discharge fees for Federal areas range from $2.50 to $4.30 per acre-foot; in State areas they range from $17.00 to $23.00 per acre-foot.

6. That the U.S. Congress authorize: (a) conversion of the San Luis Drain and Kesterson Reservoir to joint use, Federal-State facilities; and (b) completion of the San Luis Drain as a joint use, Federal-State facilities (the Valley Drain) discharging near Chipps Island.

There has been no economic analysis of the costs of soil erosion or rangeland deterioration. We do know, however, that few of the federal cost-sharing dollars are allocated to these problems. For example, the USDA's Agricultural Conservation Program in California provided approximately $576,000 dollars to deal with these problems out of a total budget of 4.5 million dollars in 1978 (most of the funding was directed toward agricultural water conservation). Further, the total amount expended for on-farm drainage systems in the same year was only $103,263 or enough to provide drainage on 500 acres or less depending upon the severity of the problem.

It is clear that present Federal programs are insufficient to deal with problems related to desertification that are occurring in California. Therefore, the State Resources Agency has sponsored legislation to provide funds for treating problems affecting California's renewable resources, which may be used in soil conservation and saline drain water management.

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ARIZONA

Category	Problem Identified
Groundwater Supply	Groundwater is generally depleted twice as fast as it is replenished, and often four or five times as fast; yet, it supports much of the State's economy; excessive overdrafts are foreseen.
Conservation	Clarifications of "beneficial use" in Arizona needed.
Flood Plain Management	Recent flooding caused property damage of over $60 million. New development is imminent where no flood plains have been delineated.
Intragovernmental Cooperation	Indian water claims could significantly affect water use patterns; also, need for allocation of interstate waters.

CALIFORNIA

Category	Problem Identified
Water Quality/ Quantity	Increasingly intensive use of water is resulting in emerging quality problems, particularly in groundwater.
Groundwater Supply	Increasing demands.
Urban Water Supply	Tremendous growth causes increasing demands. From less than 7 million people in 1940, the State's population has increased to over 22 million in 1978. Problems with quality of urban water supply system.
Conservation	California has major problems related to distribution and time of occurrence. Roughly two-thirds of the supplies occur in the northern one-third of the State while about two-thirds of the population resides in the southern one-third. Supplies are also unevenly distributed with respect to time of occurrence.
Flood Plain Management	Flooding is exacerbated by uneven distribution of rainfall over time. Majority of precipitation is in October through March. The entire State is vulnerable to varying degrees of flooding.

COLORADO

Category	Problem Identified
Water Quality/ Quantity	Salinity levels in Colorado's major rivers, especially the Upper Colorado, are a significant problem for downstream users.
Instream Flows	Formerly, all stream flows by law had to be diverted from their natural course to be put to beneficial use.
Groundwater Supply	Recharging of aquifers in the High Plains area is needed, but requires large public investments.
Urban Water Supply	The "Front Range" area is rapidly urbanizing, placing stresses on formerly adequate water supplies. These are now clearly insufficient to support both agriculture and a large urban population there.
Conservation	Conservation of water is important primarily to irrigators in the arid parts of Colorado. The State may only keep half of its total surface runoff due to interstate water agreements.
Flood Plain Management	About 1.5 million acres of land are subject to flooding and because much of it is level, fertile, and close to vital streams, it contains a large share of the State's intensive agricultural and man-made developments.
Intragovernmental Cooperation	Two Indian reservations wish to expand their water rights, while the Federal Government, owning 35% of state lands, is requiring more water. These could create an impossible burden of re-adjudication of rights and protection of individual rights.

IDAHO

Category	Problem Identified
Water Quality/ Quantity	Quality considerations may encounter or cause significant quantity problems more injurious than existing quality problems.
Instream Flows	Large amounts of high quality water are needed to maintain the aquiculture industry and to preserve free-flowing rivers' natural states.
Urban Water Supply	Urban sprawl is causing water supply problems.
Flood Plain Management	Nonstructural emphasis needed to reduce flood damage.

KANSAS

Category	Problem Identified
Instream Flows	Determination of best use of surface water, including increasing basic stream flow, must be made.
Groundwater Supply	Three-fold increase in irrigation in last decade causing groundwater declines.
Urban Water Supply	Need to match needs and supplies of communities in eastern Kansas.
Flood Plain Management	Kansas has a long history of devastating floods; total control of flooding is not possible.

MONTANA

Category	Problem Identified
Water Quality/ Quantity	Cannot logically be separated; Montana water quality standards not adequately enforced.
Instream Flows	Streams in several basins are dewatered, and others need to be protected from additional depletions, mainly due to irrigation.
Conservation	Irrigation water use accounts for most withdrawals in Montana, and its projected expansion will exacerbate existing water shortages.
Flood Plain Management	Several rivers in the State are subject to flooding.
Inadequate Water Law and/or Policy	Indian water rights and claims may not be quantified for years; also, there are increasing downstream demands for the State's water.

NEBRASKA

Category	Problem Identified
Water Quality/ Quantity	Role of irrigation unclear; irrigation may be contributing to water quality problems.
Instream Flows	Depletions due to groundwater depletion; irrigation withdrawals conflict with instream needs.
Groundwater Supply	Overwithdrawal for irrigation causes severe depletion problems in several areas; other areas experiencing buildups due to irrigation from surface supplies.
Urban Water Supply	Generally adequate.
Conservation	Irrigation is overwhelmingly the major user of ground and surface water; surface water is over-appropriated.
Flood Plain Management	A damaging flood occurs nearly every year somewhere in the State.
Intragovernmental Cooperation	A multitude of local, regional, State, and Federal agencies are involved in water and related land resources programs.

NEVADA

Category	Problem Identified
Urban Water Supply	Competition for use great. Critical problems for Las Vegas, Reno-Sparks, Carson City, Fulton area, Fallon, and Lovelock as well as Talbot Basin. By 1990, 90% of population will be urban.
Conservation	Program centers on demand reduction.
Planning & Evaluation Improvements	Overlap between hydrographic regions.

NEW MEXICO

Category	Problem Identified
Groundwater Supply	Half of all water withdrawn is groundwater; development of economic plans based on groundwater mining is necessary.

NORTH DAKOTA

Category	Problem Identified
Water Quality/ Quantity	Adverse water quality conditions are accentuated during periods of low flow, which occur annually in many streams during the late summer, fall, and winter months.
Instream Flows	During periods of low flow, stream flow is insufficient to meet minimum requirements for waste assimilation and for fish and wildlife needs.
Groundwater Supply	Highly mineralized groundwater. Large demands due to coal development. Groundwater table has declined in some areas.
Urban Water Supply	Potential water supply problems during drought periods.
Conservation	North Dakota is a water-short area.
Flood Plain Management	Extensive flood damages to both urban and rural areas. Conversion of flood plain and wetland areas to urban and agricultural uses, resulting in increased flooding.

OKLAHOMA

Category	Problem Identified
Instream Flows	Drought conditions affect communities and farmers relying on small streams for water supply.
Groundwater Supply	Depletion of groundwater supplies poses a critical problem in the western half of the State where groundwater is virtually only reliable source of water. Amount of recharge does not equal pumping. Increasing irrigation a major problem.
Urban Water Supply	Water supply in urban areas a problem as a result of depletion of groundwater.
Flood Plain Management	Rapid runoff from mountainous drainage areas result in high peak rates during storms, causing floods of short duration. Most prevalent in eastern part of the State.

OREGON

Category	Problem Identified
Water Quality/ Quantity	Concern that continuing water level declines from irrigation will result in water quality degradation.
Instream Flows	Maintenance of Columbia River flow is difficult. Existing uses account for virtually all of the available supply. Coincidence of low flow period with highest irrigation demands.
Groundwater Supply	Large number of irrigation wells depleting groundwater supplies on Columbia Slope. Elsewhere, irrigation leading to excessive groundwater declines.
Intragovernmental Cooperation	Rapidly increasing demands for Columbia River water by Oregon and adjoining States make interstate cooperative plan imperative.
Planning & Evaluation Improvements	Many early basin plans do not reflect current needs of residents, nor do they include an analysis of availability of groundwater.

SOUTH DAKOTA

Category	Problem Identified
Groundwater Supply	Increased irrigation needs.
Conservation	An important planning consideration due to recent drought conditions and a generally capricious climate.
Inadequate Law and/or Policy	Coordination of Indian and Federal reserved rights; complexity resulting from new Federal policies.
Planning & Evaluation Improvements	Water planning vital to the arid State.

TEXAS

Category	Problem Identified
Water Quality/ Quantity	Wastewater return flows presently constitute some part of the total surface water supply for users in most river basins of the State, and potentially constitute a significant part of streamflows in almost every area of the State during moderate to low-flow conditions.
Groundwater Supply	Level subsidence in population centers along the Texas coast has led to increased storm-related damage and salt water encroachment. Also, major aquifers supplying west and central Texas are being overdrafted, and could result in declines in agricultural industries.
Conservation	General statement of need for water use reductions.
Planning & Evaluation Improvements	Information from advanced analytical techniques is needed to make decisions on the water resources of the State within prevailing constraints.

UTAH

Category	Problem Identified
Water Quality/ Quantity	Salinity in the Colorado River.
Instream Flows	Reserved flows important to an arid state.
Conservation	Water distribution is the State's primary problem, since total water resources are sufficient for needs.
Planning & Evaluation Improvements	Traditional long-range comprehensive planning has been ineffective in Utah.
Statutory Environmental Compliance	Changing environmental regulations are extending planning and construction schedules.

WASHINGTON

Category	Problem Identified
Instream Flows	As a result of seasonal streamflow and demand fluctuations, some streams are in danger of being periodically dried up.
Groundwater Supply	Lack of precise aquifer data; declining water levels; saltwater intrusion.
Intragovernmental Cooperation	More than 40 entities are concerned with management of the Columbia River; Federal and Indian reserved rights are not clear, and hamper State planning; the State must adequately represent its interests in interstate, Federal, and international relationships.

WYOMING

Category	Problem Identified
Water Quality/ Quantity	Wastewater and effluent treatment plans infringing on water rights of other appropriators.
Instream Flows	Naturally wide fluctuations in stream flow altered by diversions; pressure for guaranteed flows.
Groundwater Supply	Supply is adequate, but there is a fundamental lack of understanding of groundwater movement.
Urban Water Supply	Many systems inadequate; interference by municipal wells; contaminated supplies; private ownership without State control.
Intragovernmental Cooperation	State contains headwaters for four major river basins.
Inadequate Water Law and/or Policy	Multitude of compacts and decrees governing water use and allocation.
Planning & Evaluation Improvements	State water plan out of date.
Statutory Environmental Compliance	Review and comment on various plans and EISs using increasingly greater staff resources.

				ARIZONA	CALIFORNIA	COLORADO	IDAHO	KANSAS
STATUTORY AND ADMINISTRATIVE DECLARATION OF:	Water Resources Planning and Management (lead agency)		-omnibus (integrated, single agency water quality, water quantity and related land use planning and management)					
		quality-quantity	-integrated, comprehensive water quality and water quantity planning		Water Control Board			
		quantity	-integrated, comprehensive water quantity planning and management				Dept. of Water Resources	
			-integrated, comprehensive water quantity planning		Dept. of Water Resources			Water Resources Board
			-integrated, comprehensive water quantity management	Water Commission	Water Control Board			State Engineer
		quality	-integrated, comprehensive water quality planning and management	Dept. of Health Services	Water Control Board	Water Quality Control Commission	Dept. of Environment & Community Services	Div. of Environment, Dept. of Health and Environment
	Water Quantity Planning Effort		-continuous, comprehensive		●		●	●
			-static, comprehensive				●	
			-as part of statewide natural resources planning effort					
Other Legislative Elements			-legislatively mandated mechanism for resolution of quality/quantity conflicts		●			
			-integration of water conservation with State management and/or planning programs	●				●
			-protection of instream values		●		●	
Water Rights			-prior appropriation	●	●	●	●	
			-riparian					
			-riparian-permit system superimposed					●

WATER RESOURCES PLANNING AND MANAGEMENT (Cont'd)

STATUTORY AND ADMINISTRATIVE DECLARATION OF:			MONTANA	NEBRASKA	NEVADA	NEW MEXICO	NORTH DAKOTA
Water Resources Planning and Management (lead agency)		omnibus (integrated, single agency water quality, water quantity and related land use planning and management)					
	quality quantity	-integrated, comprehensive water quality and water quantity planning					
	quantity	-integrated, comprehensive water quantity planning and management	Dept. of Natural Resources & Conservation				
		-integrated, comprehensive water quantity planning		Natural Resources Commission	Div. of Water Planning, Dept. of Conservation & Natural Resources		
		-integrated, comprehensive water quantity management		Dept. of Water Resources			Water Conservation Commission
	quality	integrated, comprehensive water quality planning and management	Dept. of Health & Environmental Sciences	Dept. of Environmental Control	Dept. of Human Resources	Water Quality Control Commission	Dept. of Health
Water Quantity Planning Effort		-continuous, comprehensive	●				
		-static, comprehensive		●	●		
		-as part of statewide natural resources planning effort		●		●	
Other Legislative Elements		-legislatively mandated mechanism for resolution of quality/quantity conflicts					●
		-integration of water conservation with State management and/or planning programs	●				●
		-protection of instream values					●
Water Rights		-prior appropriation	●	X (some riparian rights recognized)	●	●	●
		-riparian					
		-riparian-permit system superimposed					

WATER RESOURCES PLANNING AND MANAGEMENT (Cont'd)

			OKLAHOMA	OREGON	SOUTH DAKOTA	TEXAS	UTAH
STATUTORY AND ADMINISTRATIVE DECLARATION OF: Water Resources Planning and Management (lead agency)		-omnibus (integrated, single agency water quality, water quantity and related land use planning and management)					
	quality/quantity	-integrated, comprehensive water quality and water quantity planning	Water Resources Board			Dept. of Water Resources	
	quantity	-integrated, comprehensive water quantity planning and management		Water Policy Review Board			
		-integrated, comprehensive water quantity planning					Div. of Water Resources, Dept. of Natural Resources
		-integrated, comprehensive water quantity management	Water Resources Board		Water Rights Comm.	Dept. of Water Resources	State Engineer
	quality	-integrated, comprehensive water quality planning and management	Water Resources Board	Water Policy Review Board	Dept. of Environmental Protection	Dept. of Water Resources	Committee on Water Pollution, Div. of Health
Water Quantity Planning Effort		-continuous, comprehensive	●	●			●
		-static, comprehensive				●	●
		-as part of statewide natural resources planning effort			●		
Other Legislative Elements		-legislatively mandated mechanism for resolution of quality/quantity conflicts					
		-integration of water conservation with State management and/or planning programs	●	●		●	
		-protection of instream values					
Water Rights		-prior appropriation	X (some riparian rights recog.)	X (some riparian rights recognized)	X (some riparian rights recognized)	●	●
		-riparian					
		-riparian-permit system superimposed					

STATUTORY AND ADMINISTRATIVE DECLARATION OF:			WASHINGTON	WYOMING
Water Resources Planning and Management (lead agency)		omnibus (integrated, single agency water quality, water quantity and related land use planning and management)		
	quality-quantity	-integrated, comprehensive water quality and water quantity planning	Dept. of Ecology	
		-integrated, comprehensive water quantity planning and management		
	quantity	-integrated, comprehensive water quantity planning		Water Development Commission
		-integrated, comprehensive water quantity management		State Engineer
	quality	-integrated, comprehensive water quality planning and management	Dept. of Ecology	Dept. of Environmental Quality
Water Quantity Planning Effort		-continuous, comprehensive		●
		-static, comprehensive		
		-as part of statewide natural resources planning effort		
Other Legislative Elements		-legislatively mandated mechanism for resolution of quality/quantity conflicts		
		-integration of water conservation with State management and/or planning programs		●
		-protection of instream values	●	
Water Rights		-prior appropriation	●	●
		-riparian		
		-riparian-permit system superimposed		

Appendix J: Monitoring Programs

The purpose of this appendix on inventorying and monitoring is to summarize various authoritative studies which address such issues as: What is the geographical location of the section of the United States prone to desertification? What particular indicators of the desertification process make valuable targets for attention of a monitoring system? What is the present state of organization for monitoring arid regions on a global, regional and national scale? What kinds of environmental monitoring systems are currently providing data in the United States? What are the difficulties and deficiencies in our monitoring programs? Finally, what promise is seen for future coordinated efforts using improved techniques, particularly operational remote sensing systems, for observing the status and trends of land condition?

The identification and measurement of desertification processes requires inventory and subsequent monitoring of the arid and semiarid lands of the Western United States aimed at describing the present condition of the resources of the area and the nature and pace of changes in the quality of the environment. Historical data is needed to compare with the present situation and data from many different sources must be properly synthesized to accurately portray characteristics of the region.

A reliable and comprehensive monitoring system is needed to describe and quantify future trends in land conditions. This requires the coordinated application of advanced data collection, processing and analytical techniques as well as agreement on criteria and format to be used. Such information is essential to determine the extent of desertification and the nature and extent of possible remedial or mitigating actions.

The processes contributing to desertification, or the impoverishment of arid and semiarid lands, occur in the zone of net water deficiency which cover most, although not all, of the 17 Western States. More precisely, the area of the U.S. prone to desertification is an ecoregion, a discrete geographic area which can be classified according to a broad synthesis of climate and dominant physical and biological characteristics. The "Dry Domain" ecoregion is described and bounded in an accepted system, devised by R. G. Bailey and published by the Forest Service in 1976, based on land-surface form, climate, vegetation, soils, and fauna. The dry domain can be further subdivided into a number of grassland and shrub provinces according to a system which incorporates the 1966 potential natural vegetation regions of A. W. Kuchler and integrates authoritative taxonomic systems such as Hammond's land surfaces and Koopen's climates.

Identification of natural regional boundaries assists the preparation of data bases for resource inventory. If defines the area for purposes of retrieval of information and setting up systems to collect and inventory data on identified targets so that changes and trends can be monitored. Inventory and monitoring operations can be focused on specified indicators described in the ecoregions classification for arid and semiarid lands. Coordinated programs for managing problem areas can then be planned, based on consistent, measurable data covering the area of interest.

It is particularly important to distinguish between the functions of inventorying arid lands and the functions of monitoring arid lands. Inventory is a description of basic characteristics of the lands in terms of geology, vegetation, soil, and water resources. Inventory presents a static picture of the basic resource situation. Monitoring, on the other hand, provides a means of assessing the dynamics of changes in the land and its resources. Such monitoring allows one to determine the areas of change, the amount of change, and the rate of change. Monitoring of arid regions requires exchange of information between various disciplines, programs, and agencies. Monitoring is not an end in itself; rather, it provides a method for quality assurance and feedback into other aspects of desertification analysis. It provides the basis for the formulation of best practices for arid land management.

There is no distinct line between inventory and monitoring. In some instances inventory data will be utilized as the baseline from which the effects of an action are monitored, analyzed and fed back into the decisionmaking process. Conversely, monitoring data will be utilized to facilitate the development of inventories. Because these two types of data collection processes are interrelated--and in order to achieve effective and coordinated inventory and monitoring programs--all data collection efforts should adhere to the principles of quality assurance and data management and information exchange discussed under monitoring principles.

Efficient monitoring calls for a mechanism for incorporation of monitoring and inventory data into a data management and informational exchange. Such a system will provide for:

1. The efficient retrieval of information in a user-oriented format.
2. The exchange of information inside and outside the system.

Therefore, monitoring and inventory procedures should be designed to facilitate incorporation of data into a larger data base for land management.

When considering monitoring of the process of desertification, it is obvious that data collection and processing techniques will cross traditional discipline and jurisdictional boundaries. It will involve an interdisciplinary effort and will typically require cooperative arrangements between and among various federal, state, and local offices to be accomplished in a systematic way.

A large number of agencies have responsibility to provide for the multiple-use management, protection, and development of the arid and semiarid lands of the Western United States. As a result of these responsibilities, these agencies are engaged in many actions involving various forms of monitoring. These actions encompass resources above, on, and under the earth's surface, and they range in scope from local to national cooperative programs.

For example, both the Federal Land Policy and Management Act (FLPMA) and National Environmental Policy Act (NEPA) mandate that ecological whole-system values be protected.

In summary, the definition of monitoring used by BLM is: "the systematic collection of data and analysis of changes or trends (short-term and long-term) to determine (1) effects of an action on the environment, and (2) how an action complies with laws, regulations, policies, executive directives, and management decisions." By this interpretation the purpose of monitoring is to assist decisionmakers in gathering and evaluating information required for determining the effects of an action, modifying or terminating an action, mitigating effects of an action, and/or reaching better decisions about similar actions in the future.

Monitoring principles: Many land management programs are developing and using data collection and monitoring systems designed to meet both specific requirements and, increasingly, broader regional objectives. While these requirements vary, principles of (1) quality assurance, and (2) data management and information exchange need to be incorporated into monitoring efforts to provide reliable data, and insure maximum value from often expensive monitoring programs.

Quality assurance is necessary to insure reliable feedback into the decisionmaking process. It is maintained through the use of standardized techniques, instrumentation, and methodology along with adequate auditing procedures throughout all stages of sampling, measurement, and recording in the field and laboratory.

Since reliability may vary, all data utilized in the environmental analysis and decisionmaking process should be accompanied by statistical estimates of reliability to ensure maximum value to other users. This applies to data and analytical information obtained from earlier environmental studies, inventories, and information stored in environmental data bank in addition to data generated by ongoing monitoring programs.

How data will be collected, stored, and made available to all users depends upon storage and retrieval capabilities, whether the data will be stored and retrieved manually or by computer-augmented operations, and its availability in a format that is understandable and usable.

Monitoring needs may occur at any time during the decisionmaking process. However, it is desirable to consider them at the earliest possible stage in the analysis/decisionmaking process. Monitoring data may be necessary to determine whether mitigating measures are working as prescribed. It may be necessary, particularly where important values are involved, to insure that unanticipated impacts are not occurring.

The following discussion of general principles governing the use of monitoring for data collection is abstracted from a report on critical indicators in areas prone to desertification prepared for the State Department by Professors Berry and Ford.

Need for inventory and monitoring: Desertification is a complex and usually long-term process involving both natural and human elements, leading to loss of land productivity and human well-being. Desertification as a process is deserving of high-priority attention, insofar as its amelioration helps people. Three compelling needs for inventory and monitoring are indicated:

(a) Monitoring for scientific understanding.

The physical processes of ecosystem degradation--soil erosion and depletion, dune encroachment, waterlogging, and salinization--are well understood compared to other elements in the causal chain of desertification. The magnitude and rate of productivity loss from such physical processes are known only for a few scattered places and the relationship between productivity loss and human well-being is poorly understood. Development of a monitoring system must include research and experimentation to help provide the needed scientific understanding required to support a major effort.

(b) Monitoring for awareness.

Desertification is a subtle and slowing evolving process. People subjected to the effects of desertification may fail to perceive these effects as they adapt to the changing landscape or the occurrence may be obscured by short-term climatic fluctuations. The willingness to take action to reverse or prevent desertification depends on such awareness at all levels of decisionmaking--local, national, and even global. A monitoring system should be educative and directly enhance awareness of the problem at all levels of involvement.

(c) Monitoring for action.

Preventing desertification in the drylands or reversing it wherever it has occurred may exceed the capacity of national resources and might be a misallocation of resources in the face of other compelling needs. It is necessary to have early warning for preventive action and assessment for selection for remedial action. Remedial actions are seldom dramatic and they require careful observation against baseline conditions to evaluate their progress or failure. A monitoring system should assist in selecting priority areas for action and effort.

Monitoring Requirements: Based on the foregoing needs for monitoring--scientific understanding, problem awareness, and action selection--some requirements follow:

(a) The monitoring of physical processes needs to be linked to productivity loss. In addition to observation, this will require experimental design and supplemental research. Monitoring desertification is a long-term process (10 to 15 years) and requires careful institutional arrangement. The inclusion of variables related to human activities and conditions, though difficult, is critical to the success of a monitoring system. Although climate fluctuations are not the primary determining factor in desertification, the pattern of weather and climate serves to dramatize as well as obscure desertification and, therefore, should be included in the monitoring system.

(b) The ultimate monitoring system must function on several levels--local, national, regional, and, potentially, global. Satellite technology provides a supplement to local and on-ground monitoring. Significant human indicators appear meaningful on local scales. Technical knowledge presently exists to arrest desertification, reclaim degraded areas, and increase levels of productivity. But this know-how can only be effective when it is adapted to and used in the context of, local management and ecological systems.

(c) A monitoring system should provide data appropriate to its end uses. These would include educational and demonstration functions as well as to assist in policy selection. A few simple, readily understood indicators are preferable to more complex measures. Involvement of the users in the monitoring process is mandatory.

Levels of Monitoring: The purpose of this study is to address the data collection problem in the U.S. However, monitoring, to function effectively, should proceed simultaneously at all levels: local and national to begin with, and regional and global ultimately. The system should provide:

a. effective collection of a limited number of critical data;

b. analysis, as appropriate, with special emphasis on the particularity of regional and national needs and with emphasis on interrelationships between different indicators;

c. dissemination of analyses to decisionmakers and policy officials especially at the national level but not to the exclusion of other levels;

d. interchange between and among the regional, national, and local membership in the monitoring network;

e. participation, insofar as possible, of farmers and ranchers whose economies may be improved by actions resulting from an effective monitoring system.

Resources are limited. The capability of individuals and institutions to absorb comprehensive data is also limited. Thus, one problem with existing monitoring systems has been an overaccumulation and under-analysis of data. Unnecessary compilations can clog the system and overwhelm those who must use the system in quick and decisive ways. It can also add needless expense. Moreover, implementation of elaborate systems sometimes removes control from the very people whom the system was intended to benefit. It thus seems advisable to agree upon the critical variables.

International Programs for Monitoring the Earth's Environment: The subject of the first recommendations for "national and regional action" contained in the International Plan of Action to Combat Desertification approved by governments at the 1977 UN Conference on Desertification held at Nairobi, Kenya, favor desertification and the degradation processes leading to it be assessed and evaluated using both existing data and new surveys to assemble information and to carry out monitoring of the dynamics of desertification. "The assembly and evaluation of information should be a continuous process, providing a feedback mechanism for national planning and action." Action should be considered to establish machinery for assessing desertification in the following ways:

(1) To indicate the relative seriousness of the situation;
(2) To standardize monitoring facilities and methods;
(3) To improve networks of climatological, meteorological and hydrological stations. Satellite imagery techniques should be employed where appropriate. National meteorological and hydrological services should provide ongoing assessments;
(4) To monitor desertification by observing atmospheric processes, the state of vegetation and soil cover, dust transport, shifting of sand dunes, the distribution, migration and abundance of wildlife, the condition of livestock, the phenology of crops, crop yields and changes in irrigated lands;
(5) To compile desertification maps and see that they are revised through periodic assessment using appropriate techniques which will be efficient at acceptable costs.

The UN Nairobi Conference of 1977 approved two transnational projects which would establish desertification monitoring capabilities in South America and Southeast Asia. The design of these regional projects is continuing.

At the international level, the UN Environmental Program convened an "Experts Meeting on Methodology for Desertification Assessment and Mapping." The report of its meeting in Geneva, May 14-18, 1979, provided analysis of the state-of-the-art, some of the issues and problems yet to be addressed, and the character of future international work in this area.

Future programs on desertification monitoring and assessment will attempt to build on and take advantage of the work already underway within the UNEP framework. This might include direct links and collaboration with UN organizations.

In support of regional arrangements, the UNEP recommendation proposes the implementation of cooperation in the monitoring of desert processes, including the establishment of regional desertification monitoring centers, for groups of countries that are particularly vulnerable to desertification and that share ecological conditions. It also advocates a continuous system for the exchange of information among countries of the region.

A basic system for an adequate global and regional monitoring network is available within the UN EARTHWATCH structure. However, the existing UN system needs substantial improvement in the area of environmental assessment of phenomena and its relationship to human welfare needs. In addition, the EARTHWATCH system will benefit by establishment of regional and global assessment centers.

Despite an impressive array of collection activities and installations, important data gaps are reported to exist in charting the process of desertification. Decrease or increase of basic productivity of cultivated land frequently is only available through surrogate measures or estimates. Changes in productivity of rangeland are better documented but difficult to chart from currently available data. Changes in albedo and dust storms are not recorded in any systematic way and the relationship of albedo to productivity is not known for the West and Southwest of the United States. Thus, even with a substantial data base, the current system does not provide the information for a systematic documentation of the progress of desertification.

U.S. Programs for Assessing Environmental Data:

A number of U.S. agencies and institutions have responsibility for monitoring and assessing environmental processes related to desertification.

U.S. Department of Agriculture

--Soil Conservation Service, especially activities in"

Land Inventory and Monitoring (LIM) Program
Soil Conservation Needs Inventory
Conservation Operations
Great Plains Conservation Program
Range Data Systems
Soil and Land Use Surveys

--National Forest Service

Department of the Interior

--Bureau of Land Management. Monitoring federal lands under its jurisdiction.

--Bureau of Indian Affairs. Managing rangeland on American Indian lands held in trust.

--Office of Surface Mining. Monitoring recovery from strip mining.

--Geological Survey. Work relating to land use mapping, remote sensing imagery for monitoring, and geophysical hazard forecasting, and monitoring availability and quality of existing water sources.

--Fish and Wildlife Service. Habitat survey.

Dept. of Commerce, National Oceanic and Atmospheric Administration

--Climatic Change Assessment, related to the forthcoming Climate Diagnostic Center.

--National Weather Service, with both national and international coordination with World Weather Watch.

--National Environmental Satellite System (NESS), with continuing worldwide monitoring of cloud cover, vertical temperature and humidity profiles, sea surface and land temperatures, and snow and ice cover.

NASA. Remote sensing research.

Army Corps of Engineers. Project-specific mapping.

Recent Statutory Authority: The USDA RCA 1980 draft Appraisal describes several inventory and monitoring activities on which data relating to condition of Western lands is based.

Beginning in 1929, Congress began funding of inventory and monitoring activities through USDA in cooperation with other federal agencies, state and local governments and private sources. Activities included investigations on erosion control and national county Soil and Water Conservation Needs surveys.

More recently, Public Law 92-419 (August 30, 1972) authorized a land inventory and monitoring program. This program includes, but is not limited to, identifying prime agricultural producing areas and flood plains and studies and surveys of erosion, sediment damage, and land use changes and trends. The law also directed the Secretary of Agriculture to issue a land inventory report on the nation's soil, water, and related resources every five years.

The Soil and Water Resources Conservation Act of 1977, Public Law 95-192 (November 18, 1977) authorized the Secretary of Agriculture to utilize SCS to conduct a continuing appraisal of the soil, water, and related resources of the nation. In addition, the Act requires SCS to develop a soil and water conservation program based on this appraisal. This program will direct future USDA conservation efforts and guide SCS activities that are part of those efforts. The purpose of the Act is to ensure that USDA programs for conserving our soil, water, and related resources are responsive to the long-term needs of the nation, which would include combatting desertification.

The Soil Conservation Service conducts periodic monitoring and assessment of rangelands, brush, and snow.

Data show that range condition relates directly to erosion and water quality. Erosion is more likely to be excessive on rangeland in poorer condition. A 1977 special study by SCS state range conservationists estimated the percentages of the nation's nonfederal rangeland in excellent, good, fair, and poor condition. It repeated a similar range condition survey in 1963 showing state range condition.

SCS conducted national brush inventories in 1963 and 1973 (Bredemeir, 1973). The 1973 inventory showed 277 million acres of brush on nonfederal range, native pasture, pastureland, and some lands used for recreation.

SCS conducts snow survey activity described as follows in USDA Administrative Regulations 1 AR 180:

Responsibility for making and coordinating snow surveys in the western States and Alaska and preparing forecasts of seasonal water supplies in affected streams, for the purpose of relating available water supply to agricultural plans and operations.

State and Federal Data Coordination: A 1978 report by the Council of State Governments addressed the problem of coordinating data collection and use. Starting with the premise that information is the foundation on which sound decisions are made, the study found that a good deal of unneeded confusion results from failures in communication among data users and producers. Information necessary for land use management is frequently absent, sometimes improperly formatted or inconsistent. Also, it may be too expensive.

The two primary concerns of the report are (1) the improved coordination among agencies within each state collecting and using natural resource data, and (2) the improved responsiveness of federal data producers to the needs of state users.

Four recommendations from the study were: (1) compile a single data directory listing all federal data types and sources; (2) coordinate federal interagency data to ensure compatible formats and reduce duplication; (3) monitor other federal agency requirements that stimulate state data use so producers might anticipate state needs; and (4) involve states more directly in the development and programming of federal data collection activities.

Rangeland Assessment by BLM: The environmental analysis process has required BLM to describe objectively the condition of the public rangelands, the increasing public awareness and strengthening Congressional support for better management practices. BLM now believes that better inventories of the basic resources of the public rangelands, including soils, vegetation, watershed conditions, wildlife habitat, etc., are still needed so that more effective land use plans can be developed.

The National High-Altitude Photographic (HAP) Data Base Program: in 1979 several government agencies agreed to a program for the acquisition of a nationwide aerial photography data base to serve their common needs. It is planned to acquire high-altitude photography of the conterminous U.S. Funding for this program will be through interagency agreements. Agencies initially involved include the Departments of the Interior and Agriculture, NASA, EPA, and TVA. State agencies have been involved in the planning process. The photography will be available for purchase and use by public and private interests.

The Domestic Information Display System (DIDS): A growing number of federal agencies are cooperating to develop a computer system which could provide decisionmakers with almost instant access to statistics held by different government offices--and make interpreting them as easy as looking at maps. DIDS has undergone some changes but it has now been funded, and will soon be operational.

Monitoring Provisions of the Draft California Desert Plan: A practical test of inventorying the natural resource values of a region, and a good case study, is the situation which confronted BLM in preparing an Environmental Impact Statement for the California Desert. The draft report which became available in February 1980 is a case study in how data was assembled to provide a current status.

Interagency Agreement Related to Classifications and Inventories of Natural Resources: The "Interagency Agreement Related to Classifications and Inventories of Natural Resources" was signed in 1978 by the Bureau of Land Management (BLM), the Fish and Wildlife Service (FWS), the Forest Service (FS), the Soil Conservation Service (SCS), and the Geological Survey (GS) in response to several needs related to natural resource inventories including: exchange of inventory information among agencies in a consistent manner; and federal and state coordination in data collection efforts, including where applicable the use of common multi-resource inventory and analysis procedures.

Congress has recognized that the collection and analysis of natural resource information must be coordinated. This need is reflected in legislation which focuses on assessment of the resource information.

Principal objectives of the Agreement are to (1) provide guidelines and to assure administrative action to minimize duplication and overlapping efforts, and (2) to enhance and encourage coordination in overall data collection, data sharing, appraisal efficiency, program compatibility, and to expedite technology transfer. In order to accomplish the objectives of the Agreement, an organized interagency operational structure was formed with assignments of personnel from each agency to various groups. This includes a Policy Group, a Program Coordination Group, Research Support Group and Technical Work Groups. The five agencies, through the Policy Group, provide advice and consultation to the Director.

Early in the process of structuring activities to be accomplished in terms of this five-year agency effort, four major elements were identified: (1) classification, (2) data element dictionary, (3) inventory methods, and (4) information management.

(1) Classification: Sharing renewable resource information requires a common framework in which information about the land's characteristics

can be organized. Ecologically based classification systems for each of the four components which describe land in terms of soil, vegetation, water, and landform will provide the necessary hierarchical framework.

(2) Data Element Dictionary: After interagency classifications are available, common terminology must be used in this classification process as well as in inventory methods and for information management.

(3) Inventory Methods: Common inventory techniques generating compatible data are the core of the Agreement and include what and how the commonly defined data elements will be generated.

(4) Information Management: This fourth element deals with how data are stored, tabulated, analyzed, and exchanged once collected.

The first progress report from the Policy Group in fall 1979 gave the following status of topics.

1. A "Proposed National Site Classification System for Renewable Resource Inventories and Assessments" has been endorsed by all five agency heads. The soils component is quite complete, but the vegetative component needs some modification and refinement. The aquatic and landform components must still be developed.

2. A general strategy for the development of common terminology for a data element dictionary has been approved. A comprehensive dictionary is installed on BLM's computer in Denver, Colorado, and elements which are of interest to at least two of the agencies are to be maintained in a special section as Five-Agency Data Elements.

3. Two major work areas, identified in the inventory, are: (a) Identify the major renewable resource inventories being conducted by each of the five agencies, and (b) Identify specific areas for coordination among the five agencies. The inventory Technical Work Group is identifying inventories where coordination exists and where additional work is needed.

4. The last item addresses the development of standards and methods to facilitate data exchange: Information management, which is divided into two parts: (a) Consider standards needed to exchange data--such as those necessary for digitizing mapped information or other data to be placed in a computer, and (b) Study the different ways each agency handles and uses its data. The needs for information management standards are to be identified and standards completed by the end of FY 1980.

There are many stages in the work scheduled under the Agreement where a variety of individuals, groups, and organizations have an interest in the work being done.

Other state and federal organizations and interests will become involved as the need arises.

The Technical Working Group of the five agencies participating in the Interagency Agreement Related to Classifications and Inventories of Natural Resources prepared a needed chart of monitoring responsibilities, both for point source and mapped areas, for the categories of soils, vegetation, water, and landform.

Potential of Remote Sensing: Remote sensing is a tool to aid gathering information about land conditions and can be applied with a minimum of ground verification.

Assessments of the potential effects of alternative land uses requires very large quantities of information on soils, vegetative cover, water, landform (topography), and climate and their relationship to each other. Both federal and local management and planning decisions may require mapped as well as pinpointed information. The basic information required to satisfy national, state, or regional program planning, environmental impact statements, management plans, and day-to-day management operations, perhaps differing in resolution and format, place great demands on appropriate inventorying and monitoring activities. The integration, storage, processing, and management of all these kinds of data place demands on computer assistance. The collection of much of the needed data increasingly is performed by remote sensing instruments situated on aircraft and spacecraft and thus able to obtain broad coverage with great rapidity.

The amount of information extracted from remotely sensed data is dependent on the type of equipment used and the type of land to be sensed. The purpose and requirements of the data collection influence the cost and effectiveness of it, but a sensing system selected for parameters for arid lands could be initiated.

A particular advantage of remote sensing is its ability to cover remote areas or areas which do not justify the expense of ground surveys. Also, remote sensing represents a powerful analytical tool for eliminating the often high percentage of nonfragile and nonproductive areas of deserts that are of less concern, leading to the definition of the areas of critical concern that justify monitoring and documentation expense.

In 1978 a U.S. Department of Agriculture Remote Sensing User Requirements Task Force identified over 800 Forest Service natural resource information requirements which were compiled in a Data Users Requirements Task Force Catalog. Each requirement was addressed in terms of its current potential or its future potential for being classified, interpreted, or measured by remote sensing.

The review of the Remote Sensing User Requirements revealed that all these requirements can be divided into four major groups based upon application, as follows:

1. Classification and mapping applications. Units of land are classified by vegetative cover, nonvegetative cover, land use, land form, or disturbance.

2. Interpretive information for specific applications. Some examples might be the location of an unusual stress condition, potential landslide, geological hazards, and soil erosion.

3. Measurements of resource parameters. These measurements include linear distances, heights, numbers, area and other expressions of the size, quantity or quality of basic resources.

4. Observation and counts of occurrences. This category is defined as the determination of the presence or absence of an item such as erosion.

With remote sensing tools, especially Landsat, resource integration and monitoring program is feasible. Existing and new data related to geology, topography, soils, vegetation, present land use, and climate can be taken and placed in a uniform scale and known degree of accuracy to provide reliable base maps for easy reference and use.

Qualitative or quantitative data can be acquired for periodic surveillance concerning important desertification phenomena such as soil moisture, shifting and migrating sand dunes, changing vegetation patterns, degrees of salinity and alkalinity in cultivated areas whether periodic or permanent changes, and other phenomena. Repetitive data can be obtained rather quickly and cheaply from Landsat satellites with good resolution sufficient for broad reconnaissance purposes. The temperature-measuring capability of Landsat-3 and of the NOAA satellite (although at less resolution than Landsat) can be of great value in monitoring soil moisture. A study of desertification must be conducted initially on a reconnaissance level.

Appendix K: Federal Legislation on Renewable Resources Conservation and Management

2. General Existing Legislation

a. Federal

PL 42, Chapter 152

Mining Law of 1872

—An Act to promote the Development of the mining Resources of the United States.

PL 44, Chapter 107

Desert Land Act of 1877

An act to provide for the sale of desert lands in certain States and Territories—

PL 53, Chapter 301

Carey Act of 1894

SEC. 4. That to aid the public land States in the reclamation of the desert lands therein, and the settlement, cultivation and sale thereof in small tracts to actual settlers, the Secretary of the Interior with the approval of the President, be, and hereby is, authorized and empowered, upon proper application of the State to contract and agree, from time to time, with each of the States in which there may be situated desert lands as defined by the Act entitled "An Act to provide for the sale of desert land in certain States and Territories," approved March third, eighteen hundred and seventy-seven, and the Act amendatory thereof, approved March third, eighteen hundred and ninety-one, binding the United States to donate, grant and patent to the State free of cost for survey or price such desert lands, not exceeding one million acres in each State, as the State may cause to be irrigated, reclaimed occupied, and not less than twenty acres of each one hundred and sixty-acre tract cultivated by actual settlers, within ten years next after the passage of this Act, as thoroughly as is required of citizens who may enter under the said desert land law.

PL 57-161

National Irrigation Act of 1902

—An Act Appropriating the receipts from the sale and disposal of public lands in certain States and Territories to the construction of irrigation works for the reclamation of arid lands.

PL 61-435

Weeks Act of 1911

An Act To enable any State to cooperate with any other State or States, or with the United States, for the protection of the watersheds of navigable streams, and to appoint a commission for the acquisition of lands for the purpose of conserving the navigability of navigable rivers.

PL 64-290

Stock-Raising Homestead Act of 1916

An Act To provide for stock-raising homesteads, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That from and after the passage of this Act it shall be lawful for any person qualified to make entry under the homestead laws of the United States to make a stock-raising homestead entry for not exceeding six hundred and forty acres of unappropriated unreserved public land in reasonably compact form: *Provided, however*, That the land so entered shall theretofore have been designated by the Secretary of the Interior as "stock-raising lands."

PL 66-146

Mineral Leasing Act of 1920

An Act To promote the mining of coal, phosphate, oil, oil shale, gas, and sodium on the public domain.

PL 69-386

Recreation and Public Purposes Act of 1926

An Act To authorize acquisition or use of public lands by States, counties, or municipalities for recreational purposes.

PL 73-121

Fish and Wildlife Coordination Act of 1934

To promote the conservation of wild life, fish, and game, and for other purposes.

PL 73-482

Taylor Grazing Act of 1934

To stop injury to the public grazing lands by preventing overgrazing and soil deterioration, to provide for their orderly use, improvement, and development, to stabilize the livestock industry dependent upon the public range, and for other purposes.

PL 74-46

Soil Conservation and Domestic Allotment Act of 1935

To provide for the protection of land resources against soil erosion, and for other purposes.

and amendments of 1936 - PL 74-461

To promote the conservation and profitable use of agricultural land resources by temporary Federal aid to farmers and by providing for a permanent policy of Federal aid to States for such purposes.

PL 83-566

Watershed Protection and Flood Prevention Act of 1954

An Act to authorize the Secretary of Agriculture to cooperate with States and local agencies in the planning and carrying out of works of improvement for soil conservation, and for other purposes.

PL 83-585

Multiple Mineral Development Act of 1954

To amend the mineral leasing laws and the mining laws to provide for multiple mineral development of the same tracts of the public lands, and for other purposes.

PL 84-1021

Great Plains Conservation Program Act of 1955

An Act to amend the Soil Conservation and Domestic Allotment Act and the Agricultural Adjustment Act of 1938 to provide for a Great Plains conservation program.

PL 87-703

Food and Agriculture Act of 1962

> An Act to improve and protect farm income, to reduce costs of farm programs to the Federal Government, to reduce the Federal Government's excessive stocks of agricultural commodities, to maintain reasonable and stable prices of agricultural commodities and products to consumers, to provide adequate supplies of agricultural commodities for domestic and foreign needs, to conserve natural resources, and for other purposes.

PL 88-206

Clean Air Act of 1963

> (1) to protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population;
>
> (2) to initiate and accelerate a national research and development program to achieve the prevention and control of air pollution;
>
> (3) to provide technical and financial assistance to State and local governments in connection with the development and execution of their air pollution prevention and control programs; and
>
> (4) to encourage and assist the development and operation of regional air pollution control programs.

and Clean Air Act Amendments of 1977 - PL 95-05

PL 88-577

Wilderness Act of 1964

> An Act to establish a National Wilderness Preservation System for the permanent good of the whole people, and for other purposes.

PL 88-578

Land and Water Conservation Fund Act of 1965

> An Act to establish a land and water conservation fund to assist the States and Federal agencies in meeting present and future outdoor recreation demands and needs of the American people, and for other purposes.

and amendment - PL 95-42 (1977)

PL 89-80

Water Resources Planning Act of 1965

> An Act to provide for the optimum development of the Nation's natural resources through the coordinated planning of water and related land resources, through the establishment of a water resources council and river basin commissions, and by providing financial assistance to the States in order to increase State participation in such planning.

PL 89-560

Community Planning and Resource Development - Soil Surveys of 1966

> An Act to provide that the Secretary of Agriculture shall conduct the soil survey program of the United States Department of Agriculture so as to make available soil surveys needed by States and other public agencies, including community development districts, for guidance in community planning and resource development, and for other purposes.

PL 90-542

Wild and Scenic Rivers Act of 1968

> It is hereby declared to be the policy of the United States that certain selected rivers of the Nation which, with their immediate environments, possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values, shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations. The Congress declares that the established national policy of dam and other construction at appropriate sections of the rivers of the United States needs to be complemented by a policy that would preserve other selected rivers or sections thereof in their free-flowing condition to protect the water quality of such rivers and to fulfill other vital national conservation purposes.

and amendment - PL 94-486 (1976)

PL 90-583

Noxious Plant Control Act of 1968

> To provide for the control of noxious plants on land under the control or jurisdiction of the Federal Government.

PL 91-190

National Environmental Policy Act of 1969

The purposes of this Act are: To declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation; and to establish a Council on Environmental Quality.

PL 91-559

Water Bank Act of 1970

An Act to provide for conserving surface waters; to preserve and improve habitat for migratory waterfowl and other wildlife resources; to reduce runoff, soil and wind erosion, and contribute to flood control; and for other purposes.

PL 91-631

Mining and Minerals Policy Act of 1970

The Congress declares that it is the continuing policy of the Federal Government in the national interest to foster and encourage private enterprise in (1) the development of economically sound and stable domestic mining, minerals, metal and mineral reclamation industries, (2) the orderly and economic development of domestic mineral resources, reserves, and reclamation of metals and minerals to help assure satisfaction of industrial, security and environmental needs, (3) mining, mineral, and metallurgical research, including the use and recycling of scrap to promote the wise and efficient use of our natural and reclaimable mineral resources, and (4) the study and development of methods for the disposal, control, and reclamation of mineral waste products, and the reclamation of mined land, so as to lessen any adverse impact of mineral extraction and processing upon the physical environment that may result from mining or mineral activities.

PL 92-195

Wild Horses and Burros Act of 1971

It is the policy of Congress that wild free-roaming horses and burros shall be protected from capture, branding, harassment, or death; and to accomplish this they are to be considered in the area where presently found, as an integral part of the natural system of the public lands.

PL 92-516

Federal Insecticide, Fungicide and Rodenticide Act of 1971

Registration and regulation of insecticides, fungicides, and rodenticides.

and amendment PL 95-396 (1978)

PL 93-205

Endangered Species Act of 1973

To provide for the conservation of endangered and threatened species of fish wildlife, and plants, and for other purposes.

PL 93-320

Colorado River Basin Salinity Control Act of 1974

An Act to authorize the construction, operation, and maintenance of certain works in the Colorado River Basin to control the salinity of water delivered to users in the United States and Mexico.

PL 94-579

Federal Land Policy and Management Act of 1976

The Congress declares that it is the policy of the United States that—

(1) the public lands be retained in Federal ownership, unless as a result of the land use planning procedure provided for in this Act, it is determined that disposal of a particular parcel will serve the national interest;

(2) the national interest will be best realized if the public lands and their resources are periodically and systematically inventoried and their present and future use is projected through a land use planning process coordinated with other Federal and State planning efforts;

(3) public lands not previously designated for any specific use and all existing classifications of public lands that were effected by executive action or statute before the date of enactment of this Act be reviewed in accordance with the provisions of this Act;

(4) the Congress exercise its constitutional authority to withdraw or otherwise designate or dedicate Federal lands for specified purposes and that Congress delineate the extent to which the Executive may withdraw lands without legislative action;

(5) in administering public land statutes and exercising discretionary authority granted by them, the Secretary be required to establish comprehensive rules and regulations after considering the views of the general public; and to structure adjudication procedures to assure adequate third party participation, objective administrative review of initial decisions, and expeditious decisionmaking;

(6) judicial review of public land adjudication decisions be provided by law;

(7) goals and objectives be established by law as guidelines for public land use planning, and that management be on the basis of multiple use and sustained yield unless otherwise specified by law;

(8) the public lands be managed in a manner that will protect the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological values; that, where appropriate, will preserve and protect certain public lands in their natural condition; that will provide food and habitat for fish and wildlife and domestic animals; and that will provide for outdoor recreation and human occupancy and use;

(9) the United States receive fair market value of the use of the public lands and their resources unless otherwise provided for by statute;

(10) uniform procedures for any disposal of public land, acquisition of non-Federal land for public purposes, and the exchange of such lands be established by statute, requiring each disposal, acquisition, and exchange to be consistent with the prescribed mission of the department or agency involved, and reserving to the Congress review of disposals in excess of a specified acreage;

(11) regulations and plans for the protection of public land areas of critical environmental concern be promptly developed;

(12) the public lands be managed in a manner which recognizes the Nation's need for domestic sources of minerals, food, timber, and fiber from the public lands including implementation of the Mining and Minerals Policy Act of 1970 (84 Stat. 1876, 30 U.S.C. 21a) as it pertains to the public lands; and

(13) the Federal Government should, on a basis equitable to both the Federal and local taxpayer, provide for payments to compensate States and local governments for burdens created as a result of the immunity of Federal lands from State and local taxation.

PL 94-580

Resource Conservation and Recovery Act of 1976

To provide technical and financial assistance for the development of management plans and facilities for the recovery of energy and other resources from discarded materials and for the safe disposal of discarded materials, and to regulate the management of hazardous waste.

PL 95-39

Energy Research and Development Administration Act of 1977

An Act to authorize appropriations to the Energy Research and Development Administration in accordance with section 261 of the Atomic Energy Act of 1954, as amended, section 305 of the Energy Reorganization Act of 1974, and section 16 of the Federal Nonnuclear Energy Research and Development Act of 1974, and for other purposes.

It is the purpose of this Act to—

(a) establish a nationwide program to protect society and the environment from the adverse effects of surface coal mining operations;

(b) assure that the rights of surface landowners and other persons with a legal interest in the land or appurtenances thereto are fully protected from such operations;

(c) assure that surface mining operations are not conducted where reclamation as required by this Act is not feasible;

(d) assure that surface coal mining operations are so conducted as to protect the environment;

(e) assure that adequate procedures are undertaken to reclaim surface areas as contemporaneously as possible with the surface coal mining operations;

(f) assure that the coal supply essential to the Nation's energy requirements, and to its economic and social well-being is provided and strike a balance between protection of the environment and agricultural productivity and the Nation's need for coal as an essential source of energy;

(g) assist the States in developing and implementing a program to achieve the purposes of this Act;

(h) promote the reclamation of mined areas left without adequate reclamation prior to the enactment of this Act and which continue, in their unreclaimed condition, to substantially degrade the quality of the environment, prevent or damage the beneficial use of land or water resources, or endanger the health or safety of the public;

(i) assure that appropriate procedures are provided for the public participation in the development, revision, and enforcement of regulations, standards, reclamation plans, or programs established by the Secretary or any State under this Act;

(j) provide a means for development of the data and analyses necessary to establish effective and reasonable regulation of surface mining operations for other minerals;

(k) encourage the full utilization of coal resources through the development and application of underground extraction technologies;

(l) stimulate, sponsor, provide for and/or supplement present programs for the conduct of research investigations, experiments, and demonstrations, in the exploration, extraction, processing, development, and production of minerals and the training of mineral engineers and scientists in the field of mining, minerals resources, and technology, and the establishment of an appropriate research and training center in various States; and

(m) wherever necessary, exercise the full reach of Federal constitutional powers to insure the protection of the public interest through effective control of surface coal mining operations.

PL 95-113

Food and Agriculture Act of 1977

.....

The Secretary, in formulating the national program, shall take into consideration (A) the need to control erosion and sedimentation from agricultural land and to conserve the water resources on such land, (B) the need to control pollution from animal wastes, (C) the need to facilitate sound resources management systems through soil and water conservation, (D) the need to encourage voluntary compliance by agricultural producers with Federal and State requirements to solve point and nonpoint sources of pollution, (E) national priorities reflected in the National Environmental Policy Act of 1969 and other congressional and administrative actions, (F) the degree to which the measures contribute to the national objective of assuring a continuous supply of food and fiber necessary for the maintenance of a strong and healthy people and economy, and (G) the type of conservation measures needed to improve water quality in rural America.

PL 95-192

Soil and Water Resource Conservation Act of 1977

An Act to provide for furthering the conservation, protection, and enhancement of the Nation's soil, water, and related resources for sustained use, and for other purposes.

PL 95-217

Clean Water Act of 1977

The objective of this Act is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. In order to achieve this objective it is hereby declared that, consistent with the provisions of this Act—

(1) it is the national goal that the discharge of pollutants into the navigable waters be eliminated by 1985;

(2) it is the national goal that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water be achieved by July 1, 1983;

(3) it is the national policy that the discharge of toxic pollutants in toxic amounts be prohibited;

(4) it is the national policy that Federal financial assistance be provided to construct publicly owned waste treatment works;

(5) it is the national policy that areawide waste treatment management planning processes be developed and implemented to assure adequate control of sources of pollutants in each State; and

(6) it is the national policy that a major research and demonstration effort be made to develop technology necessary to eliminate the discharge of pollutants into the navigable waters, waters of the contiguous zone, and the oceans.

PL 95-237

Endangered American Wilderness Act of 1978

Congress finds and declares that it is in the national interest that certain of these endangered areas be promptly designated as wilderness within the National Wilderness Preservation System, in order to preserve such areas as an enduring resource of wilderness which shall be managed to promote and perpetuate the wilderness character of the land and its specific multiple values for watershed preservation, wildlife habitat protection, scenic and historic preservation, scientific research and educational use, primitive recreation, solitude, physical and mental challenge, and inspiration for the benefit of all of the American people of present and future generations.

PL 95-306

Renewable Resources Extension Act of 1978

Congress finds that—

(1) the extension program of the Department of Agriculture and the extension activities of each State provide useful and productive educational programs for private forest and range landowners and processors and consumptive and nonconsumptive users of forest and rangeland renewable resources, and these educational programs complement research and assistance programs conducted by the Department of Agriculture;

(2) to meet national goals, it is essential that all forest and rangeland renewable resources (hereinafter in this Act referred to as "renewable resources"), including fish and wildlife, forage, outdoor recreation opportunities, timber, and water, be fully considered in designing educational programs for landowners, processors, and users;

(3) more efficient utilization and marketing of renewable resources extend available supplies of such resources, provide products to consumers at prices less than they would otherwise be, and promote reasonable returns on the investments of landowners, processors, and users;

(4) trees and forests in urban areas improve the esthetic quality, reduce noise, filter impurities from the air and add oxygen to it, save energy by moderating temperature extremes, control wind and water erosion, and provide habitat for wildlife; and

(5) trees and shrubs used as shelterbelts protect farm lands from wind and water erosion, promote moisture accumulation in the soil, and provide habitat for wildlife.

PL 96-307

Forest and Rangeland Renewable Resources Research Act of 1978

Congress finds that scientific discoveries and technological advances must be made and applied to support the protection, management, and utilization of the Nation's renewable resources. It is the purpose of this Act to authorize the Secretary of Agriculture (hereinafter in this Act referred to as the "Secretary") to implement a comprehensive program of forest and rangeland renewable resources research and dissemination of the findings of such research.

Water Research and Development Act of 1978

It is the purpose of this Act to assist the Nation and the States through water resources science and technology—

(a) to provide a supply of water sufficient in quantity and quality to meet the Nation's expanding needs for the production of food, materials, and energy;

(b) to preserve and enhance our water resources and the water-related environment;

(c) to promote conservation and efficient use of the Nation's water resources;

(d) to promote research and development, demonstration, and technology transfer dealing with both quality and quantity of water resources;

(e) to identify and find practical solutions to the Nation's water and water resources related problems;

(f) to promote the training of scientists, engineers, and other skilled personnel in the fields related to water resources;

(g) to foster and supplement present programs for the conduct of research, technology development and transfer, and innovative water resources management, conservation, and operating practices;

(h) to provide for research, development, technology demonstration, and transfer with respect to converting saline and other impaired waters to waters suitable for municipal, agricultural, industrial, recreational, or other beneficial uses;

(i) to disseminate information through the maintenance of a water resources scientific information center with adequate information bases so that the Nation's water research community, by utilizing the center, can be fully informed of research activities and other types of information necessary for them to effectively conduct their work;

(j) to better coordinate the Nation's water resources and development programs; and

(k) to enhance the capacity of the Federal water establishment, and of water interests nationwide for recommending to the President and the Congress changes in national water resources research and technology policy as appropriate.

(a) The Congress finds and declares that—

(1) vast segments of the public rangelands are producing less than their potential for livestock, wildlife habitat, recreation, forage, and water and soil conservation benefits, and for that reason are in an unsatisfactory condition;

(2) such rangelands will remain in an unsatisfactory condition and some areas may decline further under present levels of, and funding for, management;

(3) unsatisfactory conditions on public rangelands present a high risk of soil loss, desertification, and a resultant underproductivity for large acreages of the public lands; contribute significantly to unacceptable levels of siltation and salinity in major western watersheds including the Colorado River; negatively impact the quality and availability of scarce western water supplies; threaten important and frequently critical fish and wildlife habitat; prevent expansion of the forage resource and resulting benefits to livestock and wildlife production; increase surface runoff and flood danger; reduce the value of such lands for recreational and esthetic purposes; and may ultimately lead to unpredictable and undesirable long-term local and regional climatic and economic changes;

(4) the above-mentioned conditions can be addressed and corrected by an intensive public rangelands maintenance, management, and improvement program involving significant increases in levels of rangeland management and improvement funding for multiple-use values;

(5) to prevent economic disruption and harm to the western livestock industry, it is in the public interest to charge a fee for livestock grazing permits and leases on the public lands which is based on a formula reflecting annual changes in the costs of production:

(6) the Act of December 15, 1971 (85 Stat. 649, 16 U.S.C. 1331 et seq.), continues to be successful in its goal of protecting wild free-roaming horses and burros from capture, branding, harrassment, and death, but that certain amendments are necessary thereto to avoid excessive costs in the administration of the Act, and to facilitate the humane adoption or disposal of excess wild free-roaming horses and burros which because they exceed the carrying capacity of the range, pose a threat to their own habitat, fish, wildlife, recreation, water and soil conservation, domestic livestock grazing, and other rangeland values;

(b) The Congress therefore hereby establishes and reaffirms a national policy and commitment to:

(1) inventory and identify current public rangelands conditions and trends as a part of the inventory process required by section 201(a) of the Federal Land Policy and Management Act of 1976 (43 U.S.C. 1711);

(2) manage, maintain and improve the condition of the public rangelands so that they become as productive as feasible for all rangeland values in accordance with management objectives and the land use planning process established pursuant to section 202 of the Federal Land Policy and Management Act (43 U.S.C. 1712);

(3) charge a fee for public grazing use which is equitable and reflects the concerns addressed in paragraph (a)(5) above:

(4) continue the policy of protecting wild free-roaming horses and burros from capture, branding, harassment, or death, while at the same time facilitating the removal and disposal of excess wild free-roaming horses and burros which pose a threat to themselves and their habitat and to other rangeland values

Executive Order 11644

Use of Off-Road Vehicles on the Public Lands (1972)

> It is the purpose of this order to establish policies and provide for procedures that will ensure that the use of off-road vehicles on public lands will be controlled and directed so as to protect the resources of those lands, to promote the safety of all users of those lands, and to minimize conflicts among the various uses of those lands

and as amended in Executive Order 11989 (1977)

b. State

(States will provide specific legislation.)

Appendix L: Federal and State Institutional Arrangements for Renewable Resources Conservation and Management

Introduction

The legal and institutional arrangements presented here provide a framework for cooperation. However, such a framework is not always used to its fullest and best extent. For example, one study found that the main water problems of arid and semiarid lands did not exist because of technical incapacity, but because of deficiencies in the institutional arrangements such as:

--lack of legislation to encourage conservation;
--lack of drought contingency plans; and
--lack of economic incentives to treat and recycle waste water (Fogel and Harwood/NSF, 1978).

The goals and values of closely related institutions often are seen as clashing. The trend towards greater centralization of government combined with a heightened concern for natural and wildlife resources has fostered competition rather than cooperation between the States and the Federal Government. Federal advocates make a legitimate argument that theirs is the broader jurisdictional reach and that populations of animals should be subjected only to integrated and systematic management of a sort which cannot by its nature be applied at the state level. In rebuttal, the states maintain that they, after all, are on location in the field with the personnel and the initiative to deal with the problems at ground level.

In recent years there has been a marked change in legislative trends, specially where the Department of the Interior has responsibility. Early legislation in the area of fish and wildlife, for example, was primarily concerned with the protection and preservation of food sources. The Bureau of Land Management had a custodial role until the 1976 Federal Land Policy and Management Act.

Other pieces of legislation concerning various aspects of natural resources management suggest an even broader concern. This concern reflects a more comprehensive understanding of humanity's relation to and dependence on our natural and wildlife resources (Herbst, 1979).

3. Institutional Arrangements for Renewable Resources

a. CEQ List

COUNCIL ON ENVIRONMENTAL QUALITY

Proposed List of Federal Agencies and Federal-State Agencies With Jurisdiction by Law or Special Expertise on Environmental Quality Issues

AGENCY: Council on Environmental Quality, Executive Office of the President.

ACTION: Proposed List of Federal Agencies and Federal-State Agencies with Jurisdiction by Law or Special Expertise on Environmental Quality Issues.

SUMMARY: This proposed list of Federal agencies and Federal-State agencies with jurisdiction by law or special expertise on environmental quality issues is submitted for public comment. This list will serve as a reference guide to facilitate agency compliance with the National Environmental Policy Act (NEPA) and the Regulations of the Council on Environmental Quality.

DATES: Comments must be received on or before December 18, 1979.

ADDRESSES: Comments should be addressed to Nicholas C. Yost, General Counsel, Attention—Proposed List of Federal Agencies, Council on Environmental Quality, 722 Jackson Place, N.W., Washington, D.C. 20006.

FOR FURTHER INFORMATION CONTACT: Charlotte Bell, Counsel, 202-395-4616, or Foster Knight, Counsel, (202) 395-5750, Council on Environmental Quality (address same as above).

SUPPLEMENTARY INFORMATION: This proposed list will revise Appendix II to the Council on Environmental Quality's Guidelines on the Preparation of Environmental Impact Statements (40 CFR Part 1500, 38 FR 20549, Aug. 1, 1973) which were replaced by the Council's NEPA regulations on July 30, 1979. For further information regarding the content and organization of the list, refer to its introductory paragraph.

The Council will publish in the near future a separate list of federal agency offices responsible for undertaking environmental reviews, including addresses and telephone numbers, in order to facilitate the use of this list.

We invite agencies and the public to comment on this proposed list. We are particularly interested in suggestions for improving the way in which the proposed list organizes and displays federal agencies with jurisdiction by law and special expertise on proposals involving effects on environmental quality. Please submit any comments in writing to Nicholas C. Yost, General Counsel, Council on Environmental Quality, 722 Jackson Place, N.W., Washington, D.C. 20006. Comments must be submitted by December 18, 1979 in order to receive timely consideration.

Nicholas C. Yost,
General Counsel.
October 16, 1979.

Proposed List of Federal Agencies and Federal-State Agencies With Jurisdiction by Law or Special Expertise on Environmental Quality Issues[1]

The following list is a compilation of all federal agencies with jurisdiction by law or special expertise on environmental quality issues. Agencies with "jurisdiction by law" are defined in section 1508.15 of the Council's NEPA regulations as federal agencies with authority to approve, veto or finance all or part of a proposal. Federal regulatory approval requirements (including permits and licenses) administered by agencies with jurisdiction by law are listed under the appropriate agency and marked by an asterisk (*).[2]

"Special expertise" is defined in Section 1508.26 of the NEPA regulations as statutory responsibility, agency mission or related program experience. The subject of "special expertise" is listed in parentheses opposite the appropriate agency. These designations are intended to provide examples rather than to define the limits of an agency's expertise.

The Council on Environmental Quality has prepared this list to supplement its National Environmental Policy Act (NEPA) regulations which became effective on July 30, 1979. Both the public and private sectors and governmental agencies may use this list as a reference guide to facilitate their participation in and compliance with the NEPA process. This list will be helpful in the following ways:

First, the Council on Environmental Quality's NEPA regulations require the federal agency having primary responsibility for preparing an environmental impact statement (EIS) under NEPA (the lead agency) to determine whether any other federal agencies have jurisdiction by law or special expertise with respect to any environmental effects involved in a proposal for legislation or other major federal action significantly affecting the human environment. 40 CFR 1501.5(a), 1501.6(a), 1501.7(a). The federal lead agency must, at the earliest possible time in the NEPA process, request the participation of federal cooperating agencies with jurisdiction by law or special expertise concerning the proposal. 40 CFR 1501.6(a), 1501.7(a). The lead agency and those involved in the "scoping process" (See 40 CFR 1501.7.) may use this list to help determine which other federal agencies should be requested to participate as cooperating agencies in the NEPA process.

Second, this compilation will prove useful to those whose activites or proposed actions require federal regulatory approvals by facilitating the identification of those federal agencies with the authority to issue applicable permits, licenses or other federal regulatory approvals.

Furthermore, a major goal of NEPA and the CEQ regulations is to encourage public participation in agency decisionmaking. 40 CFR 1500.2(d). Individuals, citizen groups and state and local governments who are interested in an environmental issue may use the list to help identify those agencies that have jurisdiction by law over or special expertise in a proposal. Those interested may then contact the potentially involved agencies to obtain information on the issues and to participate in the NEPA process.

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[1] River Basin Commissions (Delaware, Great Lakes, Missouri, New England, Ohio, Pacific Northwest, Souris Red-Rainy, Susquehanna, Upper Mississippi) and similar federal-state agencies should be consulted on actions affecting the environment of their special geographic jurisdictions. In all cases where a proposed action will have significant international environmental effects, the Department of State should be consulted and should be sent a copy of any draft and final impact statement that covers such action.

[2] Because laws are amended or new laws enacted, these responsibilities may change and new ones may be added. Thus, the definitive designation of an agency with jurisdiction by law depends on the law and not on this index.

The list is organized into four broad categories: pollution control, energy, land use, and natural resource management. Because some activities may fall into more than one of these categories, users of the list should consult all pertinent entries.

Index

I. Pollution Control

A. Air Pollution.
B. Water Pollution.
C. Solid Waste.
D. Noise.
E. Radiation.
F. Hazardous Substances.
Toxic Materials.
Food Additives and Contamination of Food Stuff.
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II. Energy

A. Electric Power.
B. Petroleum.
C. Natural Gas.
D. Coal and Minerals.

III. Land Use

A. Land Use Changes, Planning, and Regulation of Land Development.
B. Public Land Management.
C. Coastal Areas.
D. Environmentally Critical Areas
E. Community Development.
Built-up or Distressed Areas.
Density and Congestion Mitigation.
Neighborhood Character.
F. Historic, Architectural, and Archeological Preservation.
G. Outdoor Recreation.

IV. Natural Resource Management

A. Weather Modification.
B. Waterway Regulation and Stream Modification.
C. Soil and Plant Conservation and Hydrology.
D. Fish and Wildlife.
E. Renewable Resources.
F. Energy and Natural Resources Conservation.

I. Pollution Control

A. Air Pollution

Department of Agriculture

Forest Service (effects of air pollution on vegetation and visibility; fire smoke management).

Soil Conservation Service (effects of air pollution on vegetation; wind erosion).

Department of Commerce

National Oceanic and Atmospheric Administration (meteorological and climatological research and monitoring; urban pollution).

Department of Defense

Department of the Air Force (pollution from military aircraft).

Department of Energy

Energy Information Administration (emissions from energy sources).

- Approvals of plans for power plants and major fuel-burning facilities:

Federal Energy Administration Act of 1974, 15 U.S.C. 761–790h.

Powerplant and Industrial Fuel Use Act of 1978, Pub. L. 95–620, 92 Stat. 3289.

Department of Health, Education, and Welfare

Public Health Service:

Center for Disease Control (effects of air pollution on health).

National Institutes of Health (effects of air pollution and health).

Department of Housing and Urban Development (housing and community planning)

Department of the Interior

Bureau of Indian Affairs (Indian lands).

Bureau of Land Management (public lands).

Bureau of Mines (air pollution for mining and minerals processing and fossil and gaseous fuel combustion).

Fish and Wildlife Service (effects of air pollution on fish and wildlife).

Geological Survey (emissions from outer-continental shelf lease operations).

Heritage Conservation and Recreation Service (recreation).

National Park Service (visibility in national parks).

Office of Surface Mining Reclamation and Enforcement (surface mining).

Department of Labor

Mining Safety and Health Administration (airborne pollutants in workplace (mines)).

Occupational Safety and Health Administration (airborne pollutants in workplace.

Department of Transportation

Coast Guard (cargo tank venting and vapor recovery systems).

Federal Aviation Administration (aircraft emissions).

Federal Highway Administration (highway related air quality impacts; vehicle emissions).

Federal Railroad Administration (locomotive emissions).

Urban Mass Transportation Administration (urban transportation systems).

Environmental Protection Agency (effects of air pollution on public health and welfare; air quality criteria and standards; vehicle and aircraft emissions)

- Prevention of significant deterioration of air quality. 42 U.S.C. 7470 *et seq.*
- Application for primary non-ferrous smelter order. 42 U.S.C. 7419.
- Assuring that federal projects conform to state implementation plans under Clean Air Act. 42 U.S.C. 7616.

National Aeronautics and Space Administration (advanced technology for remote sensing of air quality parameters and for reduction of aircraft engine emissions)

Nuclear Regulatory Commission (radioactive substances)

Tennessee Valley Authority (Tennessee Valley region)

B. Water Pollution

Water Quality

Department of Agriculture

Agriculture Stabilization and Conservation Service (agricultural lands).

Forest Service (National Forest lands).

Soil Conservation Service (watershed protection)

Department of Commerce

Maritime Administration (marine pollution from ships).

National Oceanic and Atomospheric Administration (management and protection of coastal and marine resources.

Department of Defense

Army Corps of Engineers:

- Rules governing work or structures in or affecting navigable waters of the United States. 33 U.S.C. 40k, 403 and 419
- Permits for river and harbor improvement projects. 33 U.S.C. 541.
- Authority to enjoin or force removal of refuse placed in or on the banks of a navigable water or tributary of a navigable water 33 U.S.C. 407.
- Permits for private projects to improve navigable waters. 33 U.S.C. 565.
- Permits for discharges of dredged or fill materials into navigable waters. 33 U.S.C. 1344.
- Permits for transportation of dredged materials for dumping into ocean waters. 33 U.S.C. 1413.

Department of Navy (ship pollution control).

Department of Energy (energy programs)

Department of Health, Education, and Welfare

Public Health Service (effects of pollution on health).

Department of the Interior

Bureau or Indian Affairs (Indian lands).

Bureau or Land Management public lands, coastal zone management, outer continental shelf).

Bureau of Mines (mining activities).

Bureau of Reclamation (public works).

Fish and Wildlife Service (effects on fish and wildlife resources).

Geological Survey (hydrology).

Heritage Conservation and Recreation Service (effects on historic or recreational values).

National Park Service (National Parks).

Office of Surface Mining Reclamation and Enforcement (hydrologic balance in surface mining activities).

Office of Water Research and Technology (water resources planning)

Department of Transportation.

Assistant Secretary for Policy and International Affairs (environmental review of departmental programs).

Coast Guard (oil spills, ship sanitation):

- Tanker construction, equipment, manning, operation. 46 U.S.C. 391a.
- Oil and hazardous substances discharge prevention. 33 U.S.C. 1321.
- Pollution prevention (33 CFR 151, 154–6).
- Vessel navigation, waterfront facility regulations. 33 U.S.C. 1221 (50 U.S.C. 191).
- Certification of marine sanitation devices. 33 U.S.C. 1322 (33 CFR 159).

Environmental Protection Agency (treatment works; effluent limitations; oil and hazardous substance discharges)

- Permits for discharge of specific pollutants under aquaculture project. 33 U.S.C. 1328.
- Permits for disposal of sewage sludge. 33 U.S.C. 1345.
- Oil spill prevention, containment and countermeasure plans (prepared by facility owner/operator). 33 U.S.C. 1321, 1361 (40 CFR 1112.7).
- Permits for treatment, storage or disposal of hazardous wastes. 42 U.S.C. 6925.
- Temporary underground injection permits. Safe Drinking Water Act. 41 U.S.C. 300h(C)(1).
- National Pollutant Discharge Elimination System (NPDES) permits. 33 U.S.C. 1342.

Federal Maritime Commission

- Certificates of financial responsibility for water pollution. 33 U.S.C. 1321 (46 CFR Part 542): 42 U.S.C. 1643 (46 CFR Part 543); 43 U.S.C. 1815 (46 CFR Part 544).

National Aeronautics and Space Administration (advanced technology for remote sensing of water quality)

Nuclear Regulatory Commission (radioactive substances)

Tennessee Valley Authority (Tennessee Valley Region)

Water Resources Council (principles and standards)

River Basin Commissions (as geographically appropriate)

Pollution of Marine Resources

Department of Commerce

Maritime Administration (port, coastal and ocean pollution):

- Merchant vessels, polluting discharges and dumping. 46 U.S.C. 1101, *et seq.*
- Port operations, polluting discharges, and dumping. 46 U.S.C. 867 (41 Stat. 992).

National Oceanic and Atmospheric Administration (coastal zone management; ocean pollution).

Department of Defense

Army Corps of Engineers:

- Rules governing work or structures in or affecting navigable waters of the United States. 33 U.S.C. 401, 403 and 419.
- Permits for river and harbor improvement projects. 33 U.S.C. 541.
- Permits for private projects to improve navigable waters. 33 U.S.C. 5651.
- Permits for discharges of dredged or fill materials into navigable waters. 33 U.S.C. 1344.
- Permits for transportation of dredged materials for dumping into ocean waters. 33 U.S.C. 1413.
- Authority to enjoin or force removal of refuse placed in or on the banks of a navigable water or tributary of a navigable water. 33 U.S.C. 407.
- Regulation of artificial islands, installations and devices on the outer continental shelf. 43 U.S.C. 1333(e)

Department of the Navy (oceanography; pollution from ships).

Department of Energy (energy programs)

Department of Health, Education, and Welfare

Public Health Service (effects on health).

Food and Drug Administration (shellfish sanitation; contamination of fish and shellfish with toxics).

Department of the Interior

Bureau of Indian Affairs (Indian lands).

Bureau of Land Management (public lands):

- Coral harvesting (outer continental shelf). 43 U.S.C. 1334 (43 CFR 6224).
- Mineral leasing on the outer continental shelf. 43 U.S.C. 1331–1343.

Bureau of Mines (ocean mining).

Fish and Wildlife Service (effects on sport fisheries).

Geological Survey:

- Permits for geological and geophysical exploration on outer continental shelf. 43 U.S.C. 1340 (30 CFR 251).
- Permits for exploration and development activities on federal oil and gas leases on the outer continental shelf. 43 U.S.C. 1331 *et seq.* (30 CFR 250).
- Estuarine Areas Act. 16 U.S.C. 1224.

Heritage Conservation and Recreation Service (effects on historic and recreational values of marine resources).

Ocean Mining Administration (ocean-mining).

Department of State (international marine resource issues)

Department of Transportation

Coast Guard (ocean dumping enforcement, and marine resource protection).

Environmental Protection Agency

- Permits for ocean discharges. 33 U.S.C. 1343.
- Discharge of specific pollutants under aquaculture project. 33 U.S.C. 1328.
- Permits for disposal of sewage sludge. 33 U.S.C. 1345.
- Permits for transportation of ocean discharge materials. 33 U.S.C. 1412, 1414.

National Aeronautics and Space Administration (advance technology for remote sensing of water quality)

Nuclear Regulatory Commission (radioactive substances)

Water Resources Council (principles and standards for water plans)

River Basin Commissions (as geographically appropriate).

C. Solid Waste

Department of Agriculture

Forest Service (National Forests and Grasslands).

Soil Conservation Service (watershed protection).

Department of Commerce

Maritime Administration (marine pollution from ships).

Department of Defense

Army Corps of Engineers:

• Rules governing work or structures in or affecting navigable waters of the United States. 33 U.S.C. 401, 403 and 419.

• Discharge of dredged or fill materials into navigable waters. 33 U.S.C. 1344.

• Transportation of dredged materials for dumping into ocean waters. 33 U.S.C. 1413.

Department of Health, Education, and Welfare

Public Health Service:

Center for Disease Control (effects on health).

Food and Drug Administration (contamination of food resulting from disposal of municipal and industrial waste treatment sludge).

Department of the Interior

Bureau of Indian Affairs (Indian lands).

Bureau of Land Management (public lands).

Bureau of Mines (mineral waste, mine acid waste, municipal solid waste, recycling).

Geological Survey (geologic and hydrologic effects).

National Park Service (National Parks).

Office of Surface Mining Reclamation and Enforcement (surface mining wastes).

Department of Transportation

Coast Guard (ship sanitation).

Environmental Protection Agency (solid wastes and recycling—generally)

• Permits for disposal of sewage sludge. 33 U.S.C. 1345.

• Control and disposal of solid waste. —— U.S.C. ——.

• Resource Conservation and Recovery Act. 42 U.S.C. 6964 (40 CFR 3, 33, 255).

• Permits for treatment, storage, or disposal of hazardous wastes. 42 U.S.C. 6925.

• Use of restricted toxic substances—exemptions from rules/regulations. 15 U.S.C. 2601–2629.

• Transportation and handling of hazardous substances. —— U.S.C. ——.

General Services Administration (public buildings)

Nuclear Regulatory Commission (radioactive waste)

• Licensing of radioactive wastes. 42 U.S.C. 2071–2114, 5842 (10 CFR Parts 20, 40).

Tennessee Valley Authority (Tennessee Valley region)

Water Resources Council

River Basin Commissions (as geographically appropriate).

D. Noise

Department of Agriculture

Forest Service (National Forests and Grasslands).

Department of Commerce

National Bureau of Standards (measurements, standards, and methods).

Department of Defense

Department of the Air Force (military aircraft noise).

Department of Health, Education, and Welfare (effects on health)

Department of Housing and Urban Development

Office of Community Planning and Development (environmental criteria and standards for housing and land use).

Department of the Interior

Bureau of Indian Affairs (Indian lands).

Bureau of Land Management (public lands):

• Lease of public lands for airports. 49 U.S.C. 211–214 (43 CFR 2640).

• Off-road vehicle noise. (E.O. 11644). —— FR ——.

Bureau of Mines (mine noise, blasting and vibration).

Department of Labor

Mining Safety and Health Administration (noise in the workplace).

Occupational Safety and Health Administration (noise in the workplace).

Department of Transportation

Federal Aviation Administration:

Office of Environment and Energy:

• Airport construction, alteration, etc. 49 U.S.C. 1350, 1354, 1355 (14 CFR 157).

Federal Highway Administration (traffic and motor carrier noise).

Federal Railroad Administration (railroad noise).

Urban Mass Transportation Administration (transit noise).

Environmental Protection Agency

• Noise Control Act of 1972. 42 U.S.C. 4901–4918.

• National Aeronautics and Space Administration (advance technology for reduction of aircraft noise)

E. Radiation

Department of Commerce

National Bureau of Standards (measurements, standards, methods and data).

Department of Energy

Office of Energy Technology (nuclear energy).

Department of Health, Education, and Welfare

Public Health Service:

Food and Drug Administration (health and safety: contamination of food with radioactive materials).

National Institutes of Health (health).

Department of the Interior

Bureau of Indian Affairs (Indian lands).

Bureau of Land Management (public lands):

• Leases for phosphate and uranium. —— U.S.C. ——.

• Leases for withdrawal of public lands for radiation waste depository (deep burial). —— U.S.C. ——.

Bureau of Mines (uranium mines).

Geological Survey (waste disposal).

Department of Labor

Mining Safety and Health Administration (uranium mines).

Occupational Safety and Health Administration (worker exposure to sources of radiation not covered by the Department of Energy).

Department of Transportation

Federal Highway Administration:

Bureau of Motor Carrier Safety (enforcement of hazardous materials regulation for highway transportation in interstate commerce).

Environmental Protection Agency (radioactive air emissions)

Nuclear Regulatory Commission (radiation effects—generally)

• Licenses for special nuclear material. 42 U.S.C. 2073–2078 (10 CFR Part 70).

• Licenses for source material. 42 U.S.C. 2091–2099 (10 CFR Part 40).

• Licenses for by-product material. 42 U.S.C. 2111–2114 (10 CFR Parts 30–35).

• Licensing for utilization or production facilities for industrial or commercial purposes. 42 U.S.C. 2131–2133 (10 CFR Part 50).

- Licensing utilization or production facilities for medical therapy and research and development. 42 U.S.C. 2134 (10 CFR Part 50).
- Nuclear power reactor operators license. 42 U.S.C. 2137 (10 CFR Part 55).
- Licensing and regulating Department of Energy demonstration reactors. 42 U.S.C. 5842.
- Licensing Department of Energy facilities for receipt and storage of high-level radioactive wastes. 42 U.S.C. 5842.

F. Hazardous Substances

Toxic Materials

Consumer Product Safety Commission (consumer product safety)

Department of Agriculture

Agricultural Marketing Services (consumer protection).

Animal and Plant Health Inspection Service (disease vectors).

Department of Commerce

Maritime Administration (port, coastal and ocean pollution):

- Merchant vessels, polluting discharges and dumping. 46 U.S.C. 1101 *et seq.*
- Port operations, polluting discharges and dumping. 46 U.S.C. 867 (41 Stat. 992).

National Bureau of Standards (measurements, standards methods and data.)

National Oceanic and Atmospheric Administration (coastal and marine resources management and protection).

Department of Defense (military operations)

Department of Health, Education, and Welfare

Public Health Service:

Center for Disease Control (health issues).

Food and Drug Administration (contamination of food).

National institutes of Health (health issues).

Department of Housing and Urban Development

Office of Policy Development and Research (lead-based paint poisoning prevention research).

Department of the Interior

Bureau of Indian Affairs (Indians and Indian lands).

Bureau of Land Management (public lands).

Bureau of Mines (disposal methods for selected milling and mine wastes).

Fish and Wildlife Service (effects on fish and wildlife resources).

National Park Service (National parks).

Office of Surface Mining Reclamation and Enforcement (surface mining).

Department of Labor

Mining Safety and Health Administration (mining hazards).

Occupational Safety and Health Administration (workplace hazards).

Department of Transportation

Coast Guard:

- Transportation of hazardous materials by vessel. 46 U.S.C. 170, 375, 391a, 416; 49 U.S.C. 1655, 1803, 1804, 1808; 50 U.S.C. 198.
- Navigation and waterfront facility regulation. 33 U.S.C. 1221, 1224, 1321; 50 U.S.C. 191.
- Hazardous substance discharge to navigable waters. 33 U.S.C. 1321.

Federal Highway Administration.

Bureau of Motor Carrier Safety (hazardous material transportation in interstate commerce).

Federal Railroad Administration (railroad transport).

Research and Special Programs Administration (hazardous cargo, pipelines).

Materials Transportation Bureau:

- Transportation of hazardous materials. 42 U.S.C. 1805–1806.
- Permits for facilities to handle hazardous materials. 42 U.S.C. 1805–1806.

Environmental Protection Agency (hazardous air and water pollutants)

- Permits for treatment, storage or disposal of hazardous wastes. 42 U.S.C. 6925.
- Use of restricted toxic substances—exemptions from rules/regulations. 15 U.S.C. 2601–2629.
- Transportation and handling of hazardous substances. —— U.S.C. ——.

Food Additives and Contamination of Foodstuffs

Department of Agriculture

Food Safety and Quality Service (meat and poultry products).

Department of Health, Education, and Welfare

Public Heath Service.

Food and Drug Administration (effects on health).

Environmental Protection Agency (effects of pollution)

Pesticides

Department of Agriculture

Animal Plant Health and Inspection Service (control of animal and plant pests).

Food Safety and Quality Service (consumer protection).

Forest Service (National Forest and Grasslands).

Science and Education Administration (biological controls, food and fiber production).

Soil Conservation Service (watershed protection).

Department of Commerce

Maritime Administration (merchant ship operations).

National Oceanic and Atmospheric Administration (effects on marine life and the coastal zone).

Department of Defense

Armed Forces Pest Management Board (pesticide use on DOD lands, facilities and equipment; control of disease vectors).

Armed Services Explosive Safety Board (control of pests for munitions and explosive devices).

Department of Health, Education, and Welfare

Public Health Service:

Center for Disease Control (effects on health)

Food and Drug Administration (contamination of food)

Department of the Interior

Bureau of Indian Affairs (indian lands).

Bureau of Land Management (public lands).

Bureau of Reclamation (irrigated lands).

Fish and Wildlife Service (effects on fish and wildlife resources).

National Park Service (national Parks).

Department of Labor

Occupational Safety and Health Administration (worker exposures during manufacture of pesticides).

Department of Transportation

- Permits for transportation of hazardous materials. 49 U.S.C. 1805–1806.
- Approval for shipments of Class A explosives. 46 U.S.C. 170(7).
- Permits for facilities to handle hazardous materials. 49 U.S.C. 1805–1806.

Coast Guard:

- Permits for transportation of hazardous substances. 46 U.S.C. 170, 391a.
- Navigation and waterfront facility, regulation. 33 U.S.C. 1221, 1321; 50 U.S 191.

Federal Aviation Administration (transport by air).

Federal Highway Administration.

Bureau of Motor Carrier Safety (pesticide transport in interstate commerce).

Federal Railroad Administration (transport by rail).

Research and Special Programs Administration.

Materials Transportation Bureau (transport).

Environmental Protection Agency

• Permits for treatment, storage or disposal of hazardous wastes. 42 U.S.C. 6925.

• Certification of pesticide users. 7 U.S.C. 135–136y (40 C.F.R. Part 171).

• Registration of pesticides. 7 U.S.C. 163a.

• Experimental Use Permits. 7 U.S.C. 163a. (40 C.F.R. Part 172).

II. Energy

A. Electric Power Development, Generation and Transmission, and Use

Department of Agriculture

Forest Service (National Forests and Grasslands).

• Rights-of-way for electrical, communication, water facilities and roadways. 16 U.S.C. 522 *et seq.* (CFR 251.50).

Rural Electrification Adminsitration (rural areas)

• Electrical generation and transmission projects. 7 U.S.C. 901 *et seq.*

Department of Defense

Army Corps of Engineers (Hydro):

• Rules governing work or structures in or affecting navigable waters of the United States. 33 U.S.C. 403.

• Permits for discharges of dredged or fill material into navigable waters. 33 U.S.C. 1344.

• Regulation of artificial islands, installations, and devices on the outer continental shelf. 43 U.S.C. 1333(e).

Department of Energy

Federal Energy Regulatory Commission (hydroelectric power, electric transmission, electric supply, facility siting):

•Regulation of interconnection of electric transmission facilities, and regulation of enlargement of electric transmission facilities for wheeling. 16 U.S.C. 824–825K (18 CFR 32).

•Regulation of the development of water power including the licensing of non-Federal hydroelectric power projects. Federal Power Act. 16 U.S.C. 791–825r (18 CFR 4–25, 36, 131, 141).

Office of Conservation and Solar Applications (transportation industry; public buildings; industrial heating).

Office of Energy Technology (technology development).

Power Marketing Administration (as geographically appropriate).

•Approvals for plans for power plans and major fuel-burning facilities:

Federal Energy Administration Act of 1974, 15 U.S.C. 761–790h.

Powerplant and Industrial Fuel Use Act of 1978, Pub. L. 95–629, 92 Stat. 3289.

Department of Health, Education, and Welfare

Public Health Service.

National Institutes of Health (radiation effects).

Department of Housing and Urban Development (urban areas)

Department of the Interior

Bureau of Indian Affairs:

•Leases of Indian lands. 25 U.S.C. 392–403b, 415 (25 CFR Part 131).

•Leases, permits, easements of public lands. 43 U.S.C. 931c, 931d (43 CFR Part 9).

•Rights-of-way over Indian lands. 25 U.S.C. 311 *et seq.* (25 CFR Part 161); 25 U.S.C. 15 (25 CFR Parts 231–233).

Bureau of Land Management (public lands):

•Licenses for synthetic liquid fuel facilities. 30 U.S.C. 323.

•Placer mining claims on lands withdrawn or reserved for power development or power sites. 30 U.S.C. 621.

•Geothermal leases. 30 U.S.C. 1002–1011.

•Rights-of-way (various purposes, e.g., power lines and authorities). *See* 43 CFR Parts 2800, 2811, 2820, 2840, 2850, 2870, 2880, 2890.

•Mineral leasing on the outer continental shelf. 43 U.S.C. 1331–1343.

•Uranium leases (acquired lands). —— U.S.C. ——.

•Solar energy facility siting. —— U.S.C. ——.

•Public works—leases, permits, easements. 43 U.S.C. 931c, 931d (43 CFR Part 9).

Bureau of Mines (mining research).

Bureau of Reclamation.

• Public works—leases, permits, easements. 43 U.S.C. 931c, 931d (43 CFR Part 9).

Geological Survey (classification of federal lands as to their water power and water storage values).

• Geothermal lease operations. 30 U.S.C. 1023 (30 CFR 270–271).

Fish and Wildlife Service (effects on fish and wildlife resources).

• Public works—leases, permits, easements. 43 U.S.C. 931c, 931d (43 CFR Part 9).

Heritage Conservation and Recreation Service (effects on historic or recreational values).

National Park Service.

• Rights-of-way through parks or reservations for power and communications facilities. 16 U.S.C. 5.

Department of Transportation

Federal Highway Administration.

• Relocation and accomodation of utility facilities on highway rights-of-way 23 U.S.C. 109(1), 116, 123 (23 CFR Part 645).

Environmental Protection Agency (pollution control).

Nuclear Regulatory Commission

• Licensing for utilization or production facilities for industrial or commercial purposes. 42 U.S.C. 2133 (10 CFR 50).

• Nuclear power reactor operator's licneses. 42 U.S.C. 2137 (10 CFR Part 55).

• Licensing uranium milling operations. 42 U.S.C. 2091 *et seq.* (10 CFR Part 40).

• Licensing and regulating demonstration reactors. 42 U.S.C. 2134, 5842 (10 CFR Part 50).

Department of Transportation (transport of sources)

Federal Aviation Administration.

Tennessee Valley Authority (Tennessee Valley Region)

Water Resources Council (water resources planning and data)

River Basin Commissions (as geographically appropriate).

B. Petroleum Development, Extraction, Refining, Transport and Use

Department of Agriculture

Forest Service (National Forests and Grasslands).

Department of Commerce

National Oceanic and Atmospheric Administration (costal and marine resources—management and protection).

Maritime Administration (port, costal and ocean pollution).

• Merchant vessels. 42 U.S.C. 1101 *et seq.*

• Port operations. 42 U.S.C. 867 (41 Stat. 992).

Department of Defense

Army Corps of Engineers.

• Rules governing work or structures in or affecting the navigable waters of the United States. 33 U.S.C. 403.

• Permits for discharges of dredged or fill materials into navigable water. 33 U.S.C.1344.

• Regulation of artificial islands. installations. and devices on the outer continental shelf. 43 U.S.C. 1333 (c).

Department of Energy

Office of Energy Technology (technology development).

Department of the Interior

Bureau of Indian Affairs.

• Rights-of-way over Indian lands. 25 U.S.C. 311. *et seq.* (25 CFR Part 161. 171. 172. 183. 184).

• Leases for mining. oil and gas. farming and other uses on federal lands. 25 U.S.C.393 *et seq.* (25 CFR 171. 172).

Bureau of Land Management (public lands and outer continental shelf).

• Application for patents on phosphate. nitrate. oil and asphaltic mineral deposits. 30 U.S.C. 121. 122. 123.

•Oil and gas leases. 30 U.S.C. 221.

•Lease of oil and gas deposits located in rights-of-way. 30 U.S.C. 301.

•Oil pipeline rights-of-way; leases for oil shale. native asphalt. solid and semi-solid bitumen. and bituminous rock. 30 U.S.C. 241.

Bureau of Mines (environmental effects of oil mining).

Fish and Wildlife Service (effects on fish and wildlife resources).

Geological Survey.

•Oil and gas lease operations:

Public domain. 30 U.S.C. 181. *et seq.* (30 CFR 221).

Acquired land. 30 U.S.C. 351. *et seq.* (30 CFR 221).

Outer continental shelf lands. 43 U.S.C. 1331. *et seq.* (30 CFR 250. 251).

Indian lands. 25 U.S.C. 396a. *et seq.* (25 CFR 171. 172. 174. 183. 184).

•Sale and purchase of government royalty oil application. 30 U.S.C. 189. 192. 359; 43 U.S.C. 1334 (30 CFR Part 225).

Heritage Conservation and Recreation Service (effects on historical or recreational values).

National Park Service.

•Permits and leases for oil and gas. 16 U.S.C. Ch. 1.

Department of State

•Facilities for export/import of petroleum products. coal. minerals. water. sewage permits. Executive Order 14423.

Department of Transportation (transport and pipeline safety)

Coast Guard:

•Tank vessel regulation. 46 U.S.C. 391a.

•Ports and waterways safety. 33 U.S.C. 1221.

•Construction and alteration of bridges over navigable waters (for pipelines). 33 U.S.C. 525; 33 U.S.C. 494. 495; 33 U.S.C. 513–14.

•Outer continental shelf structures. 43 U.S.C. 1331.

Federal Highway Administration.

•Relocation and accommodation of pipelines on highway rights of way. 23 U.S.C. 109(1). 116. 123 (23 CFR Part 645).

Research and Special Programs Administration

Materials Transportation Bureau (pipeline safety).

Environmental Protection Agency (pollution control)

Federal Maritime Commission

Office of Environmental Analysis (carrier rates or agreements)

Interstate Commerce Commission (regulation of carriers)

C. Natural Gas Development, Production. Transmission. and Use

Department of Agriculture

Forest Service (National Forests and Grasslands).

Department of Commerce

National Oceanic and Atmospheric Administration (coastal and marine resources—management and protection).

Maritime Administration:

•Liquid natural gas vessels. 42 U.S.C. 1101. *et seq.*

•Liquid natural gas terminals. 46 U.S.C. 867 (41 Stat. 992).

Department of Defense

Army Corps of Engineers:

•Rules governing work or structures in or affecting the navigable waters of the United States. 33 U.S.C. 403.

•Permits for discharges of dredged or fill materials into navigable waters. 33 U.S.C. 1344.

•Regulation of artificial islands. installations. and devices on the outer continental shelf. 43 U.S.C. 1333(3).

Department of Energy

Federal Energy Regulatory Commission.

•Certificates for natural gas facilities (underground storage fields. LNG facilities. and transmission pipeline facilities); sale. exchange and transportation of gas; abandonment of facilities; and curtailment of natural gas service. Natural Gas Act. 15 U.S.C. 717–717w.

Department of Housing and Urban Development

Office of Community Planning and Development (residential and other lands).

Department of the Interior

Bureau of Indian Affairs.

•Leases for mining. oil and gas. farming and other uses on federal lands. 25 U.S.C. 393 *et seq.* (25 CFR 171. 172).

Bureau of Land Management (public lands):

•Application for patents on phosphate. nitrate. oil and asphaltic mineral deposits. 30 U.S.C. 121. 122. 123.

•Oil and Gas Leases. 30 U.S.C. 221.

•Lease of oil and gas deposits located in rights-of-way. 30 U.S.C. 301.

•Leasing of oil and gas deposits on the outer continental shelf. 43 U.S.C. 1331–1343.

•Gas pipeline rights-of-way. —— U.S.C. ——.

Bureau of Mines (methane; drainage and subsidence problems. Federal Helium Program).

Fish and Wildlife Service (effects on fish and wildlife resources).

Geological Survey:

•Communitization of federal oil and gas leases. 30 U.S.C. 181 *et seq.*, 315 *et seq.*

•Oil and gas lease operations:

Public domain. 30 U.S.C. 181. *et seq.* (30 CFR 221).

Acquired lands. 30 U.S.C. 351 *et seq.* (30 CFR 221).

Outer continental shelf land. 43 U.S.C. 1331 *et seq.* (30 CFR 250. 251).

Indian lands. 25 U.S.C. 3909. *et seq.* (25 CFR 171. 172. 173. 174. 183. 184).

Heritage Conservation and Recreation Service (effects on historical and recreational values).

National Park Service.

• Permits and leases for oil and gas. 16 U.S.C. Ch. 1.

Department of Transportation (transport and safety)

Coast Guard:

• Tank vessel regulation. 46 U.S.C. 391a.

• Navigation and waterfront facility regulation. 33 U.S.C. 1221. 1321; 50 U.S.C. 191.

• Construction and alteration of bridges over navigable waters (for pipelines). 33 U.S.C. 525; 33 U.S.C. 494–95; 33 U.S.C. 513–14.

• Outer continental shelf structures. 43 U.S.C. 1331.

Federal Highway Administration.

• Relocation and accommodation of pipelines on highway rights-of-way. 23 U.S.C. 109(1). 116. 123 (23 CFR Part 645).

Federal Railroad Administration (railroad transport).

Research and Special Programs Administration.

Materials Transportation Bureau (pipeline safety).

Environmental Protection Agency (pollution control)

Interstate Commerce Commission (regulation of carriers)

D. Coal and Minerals Development, Mining Conversion, Processing, Transport and Use

Appalachian Regional Commission (Appalachian region)

Department of Agriculture

Forest Service (National Forests and Grasslands):

- Surface use of public domain lands under U.S. mining laws. 16 U.S.C. 478–555 (36 CFR 252).
- Mineral development on acquired lands for solid (hardrock) minerals. 16 U.S.C. 520 (36 CFR 252), and for phosphate, oil, gas, oil shale, sodium, potassium and sulphur. 30 U.S.C. 352.
- Coal leasing. 30 U.S.C. 201–352.
- Surface coal mining operations. 30 U.S.C. 1272.
- Geothermal resource developments. 30 U.S.C. 1014.

Rural Electrification Administration.

- Financial assistance for purchase of coal mines and mining facilities. 7 U.S.C. 901 *et seq.*

Soil Conservation Service (abandoned mined land; transportation).

Department of Commerce (technical and economic information)

Department of Defense

Army Corps of Engineers:

- Rules governing work or structures on or affecting navigable waters of the United States. 33 U.S.C. 403.
- Permits for discharges of dredged or fill materials into navigable waters. 33 U.S.C. 1344.
- Authority to enjoin or force removal of refuse placed in or on the banks of a navigable water or tributary of a navigable water. 33 U.S.C. 407.

Department of Energy

Federal Energy Regulatory Commission.

- Approvals for plans for powerplants and major fuel-burning facilities:

Federal Energy Administration Act of 1974. 15 U.S.C. 761–790h.

Powerplant and Industrial Fuel Use Act of 1978. Pub. L. 95–620, 92 Stat. 3289.

Department of Housing and Urban Development

Office of Policy development and Research (subsidence).

Department of the Interior

Bureau of Indian Affairs:

- Rights-of-way over Indian lands. 25 U.S.C. 311 *et seq.* (25 CFR Part 161, 171, 172, 177).
- Leases for mining, oil and gas, farming and other uses on federal lands. 25 U.S.C. 392 *et seq.* (25 CFR Part 131, 171, 172, 177).

Bureau of Land Management (public lands):

- Patents on coal deposits. 30 U.S.C. 81, 82.
- Patents on lands with reservation of coal. 30 U.S.C. 85.
- Leases and permits for coal lands. 30 U.S.C. 181.
- Permits to take coal for domestic needs. 30 U.S.C. 208.
- Lease of mineral deposits in acquired lands. 30 U.S.C. 352.
- Lease of partial or future interests in mineral deposits. 30 U.S.C. 354.
- Leases and permits for phosphate, potassium, and sodium. 30 U.S.C. 181 *et seq:* 30 U.S.C. 351–359; Reorganization Act of July 16, 1946.
- Leases and permits for sulpher in Louisiana and New Mexico. 30 U.S.C. 181 *et seq:* 30 U.S.C. 351–359: Reclamation Act of July 16, 1946.
- Determination of unpatented mining claims. 30 U.S.C. 527.
- Mining location for source material. 30 U.S.C. 541.
- Conveyance of title to an unpatented mining claim. 30 U.S.C. 701–709.
- Leases, permits and licenses for mining in wild and scenic rivers system. 16 U.S.C. 1280.

Bureau of Mines (mining activities).

Fish and Wildlife Service (effects on fish and wildlife resources).

Geological Survey:

- Consolidation of coal leases. 30 U.S.C. 202a.
- Coal lease exploration. 30 U.S.C. 201b.
- Exploration and mining operations for leaseable minerals other than coal. 30 U.S.C. 211, 241, 261, 281. (30 CFR 231).

Heritage Conservation and Recreation Service (effects on historical and recreational values).

National Park Service:

- Leases, permits and licenses for mining subject to regulations of Secretary of the Interior on lands involved in Wild and Scenic River Systems. 16 U.S.C. 1280.
- Access permits for mining activity within the National Park System. 16 U.S.C. 1902, 1908 (36 CFR 9).

Office of Minerals Policy and Research Analysis (research).

Office of Surface Mining Reclamation and Enforcement:

- Permits for surface coal mining. 30 U.S.C. 1256–1262 (30 CFR Ch. VII).
- Permits for underground coal mining. 30 U.S.C. 1266(b) (30 CFR Ch. VII).

Department of Labor

Mine Safety and Health Administration (worker safety).

Occupational and Safety and Health Administration (worker safety in very limited situations).

Department of Transportation

Federal Highway Administration (coal haul roads, effects of railroad coal transport on roads and streets).

Federal Railroad Administration (railroad transport).

Environmental Protection Agency (pollution control)

Interstate Commerce Commission (regulation of carriers)

Tennessee Valley Authority (Tennessee Valley region)

III. Land Use

A. Land Use Changes, Planning, and Regulation of Land Development

Department of Agriculture

Agricultural Stabilization and Conservation Service (agricultural land use programs).

Forest Service (National Forest and Grasslands):

- Special use permits, archaeological permits, leases and easements. 16 U.S.C. 497; 16 U.S.C. 580d; 48 U.S.C. 341 (36 CFR 251), section 261.
- Mineral exploitation of acquired lands. 16 U.S.C. 520 (36 CFR 252).
- Easement and road rights-of-way in National Forests and other lands. 16 U.S.C. 533 (36 CFR 212.10).
- Grazing permits. 16 U.S.C. 580 (K) and (L) (36 CFR 227.1).
- Geothermal resource developments. 30 U.S.C. 1014.
- Multiple-use sustained-yield units. 16 U.S.C. 528 (36 CFR 223).
- Surface use on public domain lands under U.S. mining laws. 16 U.S.C. 478–551 (36 CFR 252).
- Minerals development on acquired lands:

Solid (hardrock) minerals. 16 U.S.C. 520.

Phosphate oil, gas, oil shale, sodium, potassium and sulphur. 30 U.S.C. 352.

- Coal leasing. 30 U.S.C. 201–352.
- Surface coal mining operations. 30 U.S.C. 1272.
- Bankhead-Jones Farm Tenant Act, Title III—Administration of national grasslands. 7 U.S.C. 1010–1012 (36 CFR 213.3).
- Claim of privately owned horses and burros. (36 CFR 222).

Economics, Statistics and Cooperatives Service (data; natural resources).

Science and Education Administration (rural and community development).

Soil Conservation Service (watershed protection).

Department of Defense

Army Corps of Engineers (flood plains).

Department of the Air Force (land use around airfields).

Department of Housing and Urban Development

Office of Interstate Land Sales (land sales).

Office of Community Planning and Development (community development; planning activities).

• Subdivided land sales, registration. Interstate Land Sales Full Disclosure Act. 15 U.S.C. 1701.

Department of the Interior

Bureau of Indian Affairs:

• Sale by Secretary of the Interior of land purchased for Indian administrative uses. 25 U.S.C. 293.

• Rights-of-way over Indian lands. 25 U.S.C. 311–328 (25 CFR 161).

• Irrigation lands. 25 U.S.C. 381 (25 CFR 191, 200).

• Leasing for mining, oil and gas, farming and other uses on federal lands. 25 U.S.C. 393 *et seq.* (25 CFR 171, 172).

• Grazing permits (25 CFR 151; 141).

Bureau of Land Management (public lands):

• Disposition of lands in Indian reservations. 30 U.S.C. 86, 87, 88.

• Limitations on entry upon saline lands. 30 U.S.C. 162.

• Securing rights-of-way for pipeline purposes. 30 U.S.C. 185(a).

• Use of surface of public lands withdrawn or reserved for power development or power sites for placer mining. 30 U.S.C. 621.

• Management of outer continental shelf for mineral leasing. 43 U.S.C. 1331–1343.

• Federal Land Policy and Management Act. 43 U.S.C. 1701 *et seq.*

• Grazing permits. Taylor Grazing Act. 43 U.S.C. 315, 315a–r.

• The Act of August 28, 1937. 43 U.S.C. 1181d.

• Mineral leases and permits under the Mineral Leasing Act of 1920, as amended. 30 U.S.C. 181 *et seq.*

• The Acquired Lands Mineral Leasing Act of 1947, as amended. 30 U.S.C. 315–359.

• Permits for underground coal mining. 30 U.S.C. 1266(b).

• Leasing lands to government or non-profit groups. 43 U.S.C. 869.

• Lease of public lands for airports. 49 U.S.C. 211–214 (43 CFR 2640).

• Special land use permits. Federal Land Policy and Management Act of 1976 (43 CFR Part 2920).

• Disposal and use of sand, stone and gravel. 30 U.S.C. 601, 602.

Bureau of Mines (minerals).

Bureau of Reclamation (public works).

Fish and Wildlife Service (effects on fish and wildlife resources).

• National Wildlife Refuge use permits. 16 U.S.C. 668dd–668ee (50 CFR 24.41).

Geological Survey (land use, geographic hazards, topographic, and photographic mapping).

Heritage Conservation and Recreation Service (conservation, national trails).

National Park Service (National Parks):

• Leases, permits and licenses for mining subject to regulations of Secretary of the Interior on lands involved in Wild and Scenic River System. 16 U.S.C. 1280.

• Access permits for mining activity within the National Park System. 16 U.S.C. 1902, 1908 (36 CFR 9).

• Special use permits, archeological permits, grazing permits, leases and easements, rights-of-way. 16 U.S.C. Ch. 1.

Office of Surface Mining Reclamation and Enforcement (surface mining).

Federal Maritime Commission

Office of Environmental Analysis (carrier rates and agreements).

Department of Transportation

Coast Guard:

• Permits for causeways. 33 U.S.C. 401.

• Bridges over navigable waters—33 U.S.C. 401, 491, 525.

• Approval of plans to alter a bridge. 33 U.S.C. 514.

Federal Aviation Administration (airports, land acquisition, release of airport property from surplus property disposal restrictions, construction or alternation of objects affecting navigable airspace, land use compatability).

Federal Highway Administration:

• Approval of highway projects and programs. 23 U.S.C. 101–158, generally, and 23 U.S.C. 204, 208–210, 212–219.

• Regulation of highway-related land use.

Highway beautification. 23 U.S.C. 131 (23 CFR Part 750)

Junkyard control and acqusition. 23 U.S.C. 136, 315 (23 CFR Part 751).

Landscapes and roadsides development. 23 U.S.C. 131, 315, 319 (23 CFR Part 752).

Environmental Protection Agency (pollution effects)

National Aeronautics and Space Administration (advanced technology for remote sensing of land use and land cover)

National Capitol Planning Commission

• Approval of land-use plans and construction in National Capitol D.C. Code 5–428; 40 U.S.C. 74a(DC Code 9–304; D.C. Code 8-104; Pub. L. 90–553, Section 4; 40 U.S.C. 122 (D.C. Code 8–115).

Water Resources Council

River Basin Commissions (as geographically appropriate)

B. Public Land Management

Department of Agriculture

Forest Service (National Forests and Grasslands management):

• Special use permits, archaeological permits, leases and easements. 16 U.S.C. 497, 16 U.S.C. 580d, 48 U.S.C. 341 (36 CFR 251); see also section 201.

• Geothermal resource developments. 30 U.S.C. 1014.

• Surface coal mining operations. 30 U.S.C. 1272.

• Coal leasing. 30 U.S.C. 201–352.

• Mining development on acquired lands.

Solid (hardrock) minerals. 16 U.S.C. 520 (36 CFR 252.

Phosphate, oil, gas, oil shale, sodium, potassium and sulphur, 30 U.S.C. 352.

• Easement and road rights-of-way in National Forests and other lands. 16 U.S.C. 533 (36 CFR 212.10).

• Grazing permits. 16 U.S.C. 580 (K) and (L) (36 CFR 227.1).

• Multiple use sustained-yield units. 16 U.S.C. 528 (36 CFR 223).

• Bankhead-Jones Farm Tenant Act, Title III—Administration of National Grasslands. 7 U.S.C. 1010–12 (36 CFR 213.3).

• Claim of privately owned horses and burros. 36 CFR 222.

Department of Defense (Lands Under Department Control)

Army Corps of Engineers (project recreation lands).

Department of the Air Force (land use around airfields).

Department of the Interior

Bureau of Indian Affairs:

• Sale by Secretary of the Interior of land purchased for Indian administrative uses. 25 U.S.C. 293.

• Leases, permits and easements on public land under the jurisdiction of BIA. 43 U.S.C. 931c, 931d (43 CFR Part 9).

• Irrigation lands. 25 U.S.C. 381 (25 CFR 203.4).

- Grazing permits. 25 CFR 151.

Bureau of Land Management:

- Placer mining claims on lands withdrawn or reserved for power development of ower sites. 30 U.S.C. 621.
- Federal Land Policy and Management Act. 433.U.S.C. 1701, *et seq*.
- Grazing permits. Taylor Grazing Act. 43 U.S.C. 315, 315a–315r.
- Act of August 28, 1937. 43 U.S.C. 1181d.
- Antiquities permits. —— U.S.C. ——.
- Special Recreation permits. —— U.S.C. ——.
- Mineral leasing on the Outer Continental Shelf. 43 U.S.C. 1331–1343.
- Leases, permits and licenses for mining in Wild and Scenic Rivers Areas. 16 U.S.C. 1280.
- Leasing lands to government or non-profit groups. 43 U.S.C. 869.
- Lease of public lands for airports. 49 U.S.C. 211–214 (43 CFR 2640).
- Rights-of-way (various purposes (e.g., roads, railroads power lines, irrigation, pipelines, mineral leasing) and authorities). *See* 43 CFR Parts 2800, 2811, 2820, 2840, 2850, 2870, 2880, 2890.
- Special land use permits. Federal Land Policy and Management Act of 1976 (43 CFR Part 2920).
- Disposal and use of sand, stone and gravel. 30 U.S.C. 601, 602.

Bureau of Mines (mineral land assessment).

Fish and Wildlife Service (effects on fish and wildlife resources).

Geological Survey:

- Outer Continental Shelf. 43 U.S.C. 1331–1343.
- Onshore oil, gas, mining. 30 U.S.C. 181 *et seq*.
- Onshore oil, gas, mining on Indian lands. 25 U.S.C. 396, 396a–298. 35 Stat. 812.
- Geothermal. 30 U.S.C. 1023.

Heritage Conservation and Recreation Service (conservation, fund state programs).

National Park Service (public lands):

- Leases, permits and licenses for mining subject to regulations of Secretary of the Interior on lands involved in Wild and Scenic River System. 16 U.S.C. 1280.
- Access permits for mining activity within the National Park System. 16 U.S.C. 1902, 1908 (36 CFR 9).
- Special use permits, archeological permits, grazing permits, leases and easements, rights-of-way. 16 U.S.C. Ch. 1.

Office of Surface Mining Reclamation and Enforcement:

- Permits for surface coal mining. 30 U.S.C. 1256–1262.
- Permits for underground coal mining. 30 U.S.C. 1266(b).

Department of Transportation

- Transportation programs with measures to protect land traversed (particularly parks, recreation areas and historic sites). Department of Transportation Act as amended. 49 U.S.C. 1651–1659.

Federal Highway Administration (construction and management of National Park Service roads and forest highways):

- Approval of projects for Indian reservation roads and bridges. 23 U.S.C. 208.
- Construction of public lands highways. 23 U.S.C. 209.
- Approval of projects for public lands development roads and trails. 23 U.S.C. 214.

General Services Administration (public buildings management)

Federal Property Resources Service (excess land disposal).

National Aeronautics and Space Administration (advanced technology remote sensing of land use and land cover)

Tennessee Valley Authority (project lands)

C. Land Use in Coastal Areas

Department of Agriculture

Forest Service (National Forest and Grasslands).

Soil Conservation Service (soil stability, hydrology).

Department of Commerce.

Maritime Administration (ports).

National Oceanic and Atomospheric Administration (coastal and marine resources and protection):

- Permits for activities in designated marine sanctuaries. 16 U.S.C. 143 *et seq.* (15 CFR 922).
- Approval and funding of state coastal management programs. 16 U.S.C. 1451 *et seq.* (15 CFR 923, 930).
- Protection of endangered species and critical habitats. 16 U.S.C. 1531 *et seq.* (50 CFR 222).
- Establishment of estuarine santuaries. 16 U.S.C. 1461 (15 CFR 921).

Department of Defense

Army Corps of Engineers (beaches, dredge and fill permits, Refuse Act permits):

- Rules governing work or structures in or affecting navigable waters of the United States. 33 U.S.C. 401, 403 and 419.
- Authority to enjoin or force removal of refuse placed in or on the banks of a navigable water or tributary of a navigable water 33 U.S.C. 407.
- River and harbor improvement projects. 33 U.S.C. 541.
- Permits for private projects to improve navigable waters. 33 U.S.C. 565.
- Permits for discharges of dredged or fill materials into navigable waters. 33 U.S.C. 1344.
- Permits for transportation of dredged materials for dumping into ocean waters. 33 U.S.C. 1413.

Department of Housing and Urban Development (development in coastal areas)

Department of the Interior

Bureau or Indian Affairs (Indian lands).

Bureau or Land Management (public lands):

- Cooperation with states in developing coastal zone plans. 86 Stat. 1280.
- Limitations on entry upon saline lands. 30 U.S.C. 162.
- Mineral leasing on the outer continental shelf. 43 U.S.C. 1331–1343.

Fish and Wildlife Service (effects on fish and wildlife resources).

Geological Survey (estuarine areas):

- Permits for geological and geophysical exploration on outer continental shelf. 43 U.S.C. 1340 (30 CFR 251).
- Permits for exploration and development activities on federal oil and gas leases on the outer continental shelf. 43 U.S.C. 1331 *et seq.* (30 CFR 250).

Heritage Conservation and Recreation Service (historical and recreational values).

National Park Service (barrier island ecology and coastal processes).

Department of Transportation

Coast Guard (bridges, navigation and deepwater ports):

- Bridges over navigable waters—permits 33 U.S.C. 525.
- Approval of plans to alter a bridge. 33 U.S.C. 514.
- Permits for causeways. 33 U.S.C. 401.
- Waterfront facilities. 33 U.S.C. 1221, 1321.
- Deepwater port regulation. 33 U.S.C. 1503–1524.
- Vessel operating requirements. —— U.S.C. ——.
- Licensing of persons to engage in the ownership, construction or operation of a deepwater port. 33 U.S.C. 1503–1520.

Environmental Protection Agency (pollution effects):

- Permits for ocean discharges. 33 U.S.C. 1343.
- Permits for disposals of sewage sludge. 33 U.S.C. 1345.

- Oil spills prevention, containment, and countermeasure plans (prepared by facility owner/operator). Sections 3111, 501, 33 U.S.C. 1321, 1361 (40 CFR 112.7).

Federal Maritime Commission. Office of Environmental Analysis (terminal agreements).

National Aeronautics and Space Administration (advanced technology for remote sensing of land use and land cover).

D. Protection of Environmentally Critical Areas—

Floodplains, Wetlands, Beaches and Dunes, Unstable Soils, Steep Slopes, Aquifer Recharge Areas, Tundra, Etc.

Department of Agriculture

- Watershed Protection and Flood Prevention Act. 16 U.S.C. 1001–1009 (7 CFR Parts 15, 23, 600).

Agricultural Stabilization and Conservation Service (commodity and land use programs: Water Bank).

Forest Service (National Forest lands).

Science and Education Administration (soil and water conservation program).

Soil Conservation Service (watershed protection and flood control: soil and water conservation).

Department of Commerce

National Oceanic and Atmospheric Administration (coastal and marine resources, management and protection):

- Protection of endangered species and critical habitats. 16 U.S.C 1531, *et seq.* (50 CFR 222)
- Permits for activities in designated marine sanctuaries. 16 U.S.C. 1431, *et seq.* (15 CFR 922).
- Establishment of estuarine sanctuaries. 16 U.S.C. 1461 (15 CFR 921).
- Approval and funding of state coastal management programs. 16 U.S.C. 1451 *et seq.* (15 CFR 923; 930).

Department of Defense

Army Corps of Engineers:

- Permits for discharge of dredged or fill materials into navigable waters. 33 U.S.C. 1344.
- Rules governing work or structures in or affecting navigable waters of the United States. 33 U.S.C. 401, 403, 419.

Department of Health, Education, and Welfare

Public Health Service.

Center for Disease Control (health issues).

Department of Housing and Urban Development

Office of Community Planning and Development (urban and floodplain areas).

Department of the Interior

Bureau of Indian Affairs (Indian lands).

Bureau of Land Managment:

- Limitations on entry upon saline lands. 30 U.S.C. 162.
- Management of areas of critical environmental concern. 43 U.S.C. 1701.

Bureau of Reclamation (public works).

Fish and Wildlife Service (protection of fish and wildlife resource values).

Geological Survey (topography, geology, hydrology).

Heritage Conservation and Recreation Service (historical and recreational values).

National Park Service (National Park lands).

Office of Surface Mining Reclamation and Enforcement (designation of areas unsuitable for surface coal mining).

Office of Water Research and Technology (water resource planning).

Department of Transportation

Coast Guard.

- Establishment of port access routes. 33 U.S.C. 1221.

Federal Highway Administration:

- Approval of federal-aid highway projects. 23 U.S.C. 101–156, generally.
- Approval of highway bridge replacement and rehabilitation. 23 U.S.C. 144 (23 CFR Part 650).

Environmental Protection Agency (pollution effects)

- Temporary underground injection permits. Safe Drinking Water Act. 42 U.S.C. 300h(C)(1).

Water Resources Council (coordination of floodplain and wetland initiatives)

River Basin Commissions (as geographically appropriate).

E. Community Development

Advisory Council on Historic Preservation (historic preservation)

Department of Agriculture

Science and Education Administration (rural and community development program).

Soil Conservation Service (soil survery).

Department of Commerce

Economic Development Administration (designated areas).

Department of Health, Education, and Welfare

Public Health Service.

Center for Disease Control (health).

Office of Human Development Services (problems of handicapped, aged, children and Native Americans).

Department of Housing and Urban Development

Office of Community Planning and Development (community development: effects on low income populations: economic revitalization in distressed areas: density and congestion mitigation: rehabilitation and urban homesteading).

Department of the Interior

Bureau of Indian Affairs (Indian Lands).

Geological Survey (flood, seismic, and geologic hazards).

Heritage Conservation and Recreation Service (landmarks, archeological remains, outdoor recreation, historic preservation).

Department of Transportation

Federal Aviation Administration (airports).

Federal Highway Administration:

- Relocation assistance in connection with highway projects. 42 U.S.C. 4601 *et seq.* (23 CFR Part 740, 49 CFR Part 25).
- Approval of economic growth center development highways. 23 U.S.C. 143.

Urban Mass Transportation Administration.

- Urban Mass Transportation Act. 49 U.S.C. 1610.

Environmental Protection Agency (pollution control)

General Services Administration (building design and construction)

National Capitol Planning Commission (Washington, D.C. area)

- Approval of Land use plans and construction in the National Capitol. D.C. Code 5–428, 40 U.S.C. 74a (D.C. Code 9–304); D.C. Code 8–104; Pub. L. 90–553, section 4; 40 U.S.C. 122 (D.C. Code 8–115).

National Endowment for the Arts (artistic values)

F. Historic, Architectural, and Archeological Preservation

Advisory Council on Historic Preservation (historic preservation)

Department of Agriculture

Forest Service (National Forest and Grasslands).

Department of Housing and Urban Development (in urban areas)

Department of the Interior

- Permits to examine ruins, excavations and gathering of objects on land under jurisdiction of Interior, Agriculture and Army. 16, U.S.C. 432.

Bureau of Indian Affairs (Indian lands).

- Preservation of antiquities. 16 U.S.C. 432 (25 CFR 132).

Bureau of Land Management (public lands).

- Antiquities search and collection permit. Antiquities Act. 16 U.S.C. 432 (43 CFR 3).

Heritage Conservation and Recreation Service (historic and cultural landmarks):

- Antiquities Act of 1906. 16 U.S.C. 431–433 (43 CFR 3). National Historic Preservation Act of 1966. 16 U.S.C. 470 *et seq.*
- Archaeological and Historic Preservation Act. 16 U.S.C. 469.

National Park Service (National Park lands).

Department of Transportation

- Approval of transportation programs or projects that require the use of an historic site. 42 U.S.C. 1653(f).

Federal Highway Administration.

- Approval of transportation programs or projects that require the use of an historic site. 42 U.S.C. 138.
- Archeological and paleontological salvage on federal and federal-aid highway projects. 23 U.S.C. 305 (23 CFR Part 765).

General Services Administration

(Public Buildings Service (in urban areas).

National Capitol Planning Commission

- Approval of land use plans and construction in National Capitol. D.C. Code 5–428; 40 U.S.C. 74a (D.C. Code 9–304); D.C. Code 8–104; Pub. L. 90–553, section 3; 40 U.S.C. 122 (D.C. Code 8–115).

National Endowment for the Arts

G. Outdoor Recreation

Department of Agriculture

Forest Service (National Forest land).
Soil Conservation Service (watershed protection).

Department of Defense

Army Corps of Engineers (recreation areas on DOD lands).

Department of Health, Education, and Welfare

Public Health Service.
Center for Disease Control (Health).

Department of Housing and Urban Development (urban areas)

Department of the Interior

Bureau of Indian Affairs (Indian ands).
Bureau of Land Management (public ands).
Fish and Wildlife Service (effects on fish and wildlife resources).
Heritage Conservation and Recreation Service.

- Land and Water Conservation Act. 16 U.S.C. 460(L)4–(L)11–(L)22.

National Park Service (National park lands).

Department of Transportation

Coast Guard.

- Recreational boating regulation. 46 U.S.C. 1451.

Federal Highway Administration:

- Preservation of parklands. 23 U.S.C. 138.
- Access highways to public recreation areas on lakes. 23 U.S.C. 155.

Environmental Protection Agency (pollution control)

Water Resources Council (water and related land resources)

River Basin Commission (as geographically appropriate)

IV. Natural Resource Management

A. Weather Modification

Department of Agriculture

Forest Service (National Forests and Grasslands).
Soil Conservation Service (snow survey).
World Food and Agricultural Outlook and Situation Board (data relating to commodities).

Department of Commerce

National Oceanic and Atmospheric Administration (research and development; reports on private activities).

Department of Defense

Department of the Air Force (fog dissipation).

Department of the Interior

Bureau of Reclamation (water resources research).
National Park Service (public lands).

B. Waterway Regulation and Stream Modification

Department of Agriculture

Agricultural Stabilization and Conservation Service (resource conservation; Water Bank).
Forest Service (National Forests and Grasslands).
Science and Education Administration (soil and water conservation).
Soil Conservation Service (watershed protection).

Department of Commerce

Maritime Administration (merchant vessels, barges and inland vessels).

Department of Defense

Army Corps of Engineers:

- Rules governing work or structures in or affecting navigable waters of the United States. 33 U.S.C. 401, 403, and 419.
- Permits for discharges of dredged or fill materials into navigable waters. 33 U.S.C. 1344.

Department of the Interior

Bureau of Indian Affairs (Indian lands).
Bureau of Land Management (Public lands).
Bureau of Reclamation (public works).
Fish and Wildlife Service (effects on fish and wildlife resources).
Geological Survey (hydrology).
National Park Service (National Parks).

Department of Transportation

Coast Guard (vessels, bridge, port, and waterway safety; navigation aids):

- Deepwater port regulation. 33 U.S.C. 1503–1524.
- Tank vessel regulation. 46 U.S.C. 391a.
- Ports and waterways safety. 33 U.S.C. 1221.
- Construction and alterations on bridges and causeways over navigable waters. 33 U.S.C. 401, 491, 525; 33 U.S.C. 494–95; 33 U.S.C. 513–14).

Federal Highway Administration:

- Approval of federal-aid highway and bridge projects involving navigable waters and channel changes. 23 U.S.C. 144 (23 CFR Part 650)
- Approval of toll bridge and ferry projects. 23 U.S.C. 129.

Environmental Protection Agency (pollution control)

Federal Maritime Commission

Office of Environmental Analysis (approval of terminal agreements).

Water Resources Council

- Water Resources Planning Act. 42 U.S.C. 1962 (18 CFR 701–706; 33 CFR 252).

River Basin Commissions (as geographically appropriate).

C. Soil and Plant Conservation and Hydrology

Department of Agriculture

Agricultural Stabilization and Education Service (soil conservation).
Farmers Home Administration (soil erosion).
Forest Service (National Forest lands).
Science and Education Administration (water and soil conservation).
Soil Conservation Service (soil and watershed conservation).

• Grazing Permits. 16 U.S.C. 580 (K) and (L) (36 CFR 227.1).

• Multiple-use sustained-yield units. 16 U.S.C. 528 (36 CFR 223).

• Bankhead-Jones Farm Tenant Act, Title III—Administration of National Grasslands. 7 U.S.C. 1010–1012 (36 CFR 213.3).

Department of Commerce

National Oceanic and Atmospheric Administration (coastal and marine resources-management and protection).

Department of Defense

Army Corps of Engineers (dredging, aquatic plants).

Department of the Interior

Bureau of Indian Affairs (Indian lands):

• Irrigation lands. 25 U.S.C. 381 (25 CFR 203.4).

• Timber cutting permits. 25 CFR 141.19.

• Grazing permits. 25 CFR 151.

Bureau of Land Management (public lands).

• Timber permits for free use. 30 U.S.C. 601 *et seq.*, 189; 43 U.S.C. 315, 1201; 48 U.S.C. 423 (43 CFR Part 5010).

Bureau of Mines (hydraulic effects of mining).

Bureau of Reclamation (public works).

Fish and Wildife Service (effects on fish and wildlife resources).

• Endangered plants—permit. 50 CFR 17.62.

Geological Survey (geology).

National Park Service (National park lands).

• Special use permits, grazing permits, permits to collect soil, rock, water, and plant specimens. 16 U.S.C. Ch. 1, 3.

Department of Transportation

Federal Highway Administration (erosion control in highway projects).

Environmental Protection Agency (pollution control)

National Aeronautics and Space Administration (advanced technology for remote sensing of land covers)

Water Resources Council (floodplain and wetland initiatives)

River Basin Commissions (as geographically appropriate).

D. Fish and Wildlife

Department of Agriculture

Animal and Plant Health Inspection Service (importation of wildlife and birds; endangered species enforcement).

Forest Service (National Forests and Grasslands):

• Claim of privately owned horses and burros. 36 CFR 222.

Soil Conservation Service (habitat, fish ponds, aquaculture).

Department of Commerce

National Oceanic and Atmospheric Administration (coastal and marine resources management and protection):

• Permit for importing marine mammals or products thereof. 16 U.S.C. 1371, 73, 74 (50 CFR 216).

• Scientific research and public display of marine mammals. 50 CFR 618; 50 CFR 216.31, 220.

• Control of fishing by foreign and domestic vessels. 16 U.S.C. 1801, *et seq.* (50 CFR Ch. VI).

• Fish and Wildlife Coordination Act. 16 U.S.C. 1361, *et seq.*

• Permits for activities in designated marine sanctuaries. 16 U.S.C. 1431, *et seq.* (15 CFR 922).

• Approval and funding of state coastal management programs. 16 U.S.C. 1451, *et seq.* (15 CFR 923; 930).

• Protection of endangered species and critical habitats. 16 U.S.C. 1531, *et seq.* (50 CFR 222).

• Protection of marine mammals. 16 U.S.C. 1361, *et seq.* (50 CFR 216).

• Establishment of estuarian sanctuaries. 16 U.S.C. 1461 (15 CFR 921).

• Trustee of natural resources. 43 U.S.C. 1813 (E.O. 12123).

• Scientific, propagation or survival of marine reptile—permits. 50 CFR 227.72.

National Marine Fisheries Service (endangered species).

Department of Defense

Department of the Air Force (bird-aircraft strike hazard reduction).

Department of the Interior

Bureau of Indian Affairs (off-reservation treaty fishing).

Bureau of Land Management (wild horses and burros; public lands).

Fish and Wildlife Service (endangered species; effects on fish and wildlife):

• Bald and golden eagle protection—permits (takings for scientific, agricultural, other uses). 16 U.S.C. 668–668d.

• Permits for endangered species export and import. 16 U.S.C. 1538(d).

• Permits for scientific research involving endangered species. 16 U.S.C. 1539.

• Mitigation/compensation for harm to endangered or threatened species or critical habitat. 16 U.S.C. 1539.

• Permits for taxidermy on migratory birds, nests, or eggs for commercial uses. 16 U.S.C. 704.

• Fish and Wildlife Coordination Act. 16 U.S.C. 661 *et seq.* (43 CFR Part 17).

• Anadromous Fish Conservation Act. 16 U.S.C. 755 *et seq.*

Heritage Conservation and Recreation Service (outdoor recreation).

National Park Service:

• Permits for collecting animal specimens from National Park System areas. 16 U.S.C. Ch. 1, 3.

• Licenses and permits for sport or commercial fishing in certain National Park System areas. 16 U.S.C. Ch. 1, 3.

• Disposition of surplus animals from National Park System areas. 16 U.S.C. Ch. 1, 3.

Department of Health, Education, and Welfare

Public Health Service (health).

Food and Drug Administration (contamination of fish and shellfish with toxics).

Department of Transportation

Federal Highway Administration (highway construction).

Environmental Protection Agency (effects of water pollution)

Department of State (international issues)

E. Renewable Resource Development, Production, Management, Harvest, Transport and Use

Department of Agriculture

Economic Statistical Cooperation Service (data).

Forest Service (timber sale, free use and other timber management activities in National Forests and Grasslands).

Science and Education Administration (forest and range management).

Soil Conservation Service (watershed protection; soil conservation).

Department of Commerce

National Oceanic and Atmoshperic Administration (coastal and marine resources management and development).

Department of Defense

Army Corps of Engineers (hydro).

Department of Energy (hydroelectric power, Office of Conservation and Solar Applications).

Federal Energy Regulatory Commission.

• Regulation of development of water resources. Federal Power Act. 16 U.S.C. 791–825r (18 CFR 4–25, 36, 131, 141).

Department of Housing and Urban Development (building materials)

Department of the Interior

Bureau of Indian Affairs (Indian lands).

• Leases of Indian lands. 25 U.S.C. 392–403b, 415, (25 CFR Parts 131, 141–

142, 144, 151–153, 231–233). 25 U.S.C. 311 *et seq.* (*25 CFR Part 161*).

• Rights-of-way over Indian lands. 141, 142, 144, 151–153, 231–233.

Bureau of Land Management (public lands).

• Federal Land Policy and Management Act. 43 U.S.C. 1701 *et seq.*

• Grazing permits. Taylor Grazing Act. 43 U.S.C. 315, 315a–4.

• The Act of August 28, 1937. 43 U.S.C. 1181d.

Bureau of Reclamation (public works).

Fish and Wildlife Service (effects on fish and wildlife resources).

Heritage Conservation and Recreation Service (effects on historical and recreational values).

National Park Service (National Park lands).

• Permits for sport fishing, hunting and grazing. 16 U.S.C. Ch. 1, 3.

Department of Transportation

Federal Highway Administration (logging haul roads, access roads).

Environmental Protection Agency (pollution control)

Federal Maritime Commission

Office of Environmental Analysis (carrier rates).

Interstate Commerce Commission (freight rates)

F. Energy and Natural Resources Conservation

Department of Agriculture

Agricultural Stabilization and Conservation Service (resource conservation).

Forest Service (National Forests and Grasslands).

Science and Education Administration (soil and water conservation; forest and range management).

Soil Conservation Service (soil and water conservation).

Department of Energy

• Energy Conservation Standards for New Buildings Act. 42 U.S.C. 6834.

Federal Energy Regulatory Commission (hydroelectric power and natural gas facilities).

Department of Commerce

National Bureau of Standards (energy efficiency).

National Oceanic and Atmospheric Administration (coastal and marine resources—management and protection).

Department of Housing and Urban Development

Office of Housing (previously FHA) housing standards).

Office of Policy Development and Research (energy, building technology and standards research).

Department of the Interior

Bureau of Indian Affairs (Indian resources).

Bureau of Land Management (public lands).

Bureau of Mines (land reclamation; recycling; and processing and use of materials).

Bureau of Reclamation (water projects).

Geological Survey (oil and gas storage).

• Geothermal lease operations. 30 U.S.C. 1023 (30 CFR 270).

[FR Doc. 79-32331 Filed 10-18-79; 8:45 am]

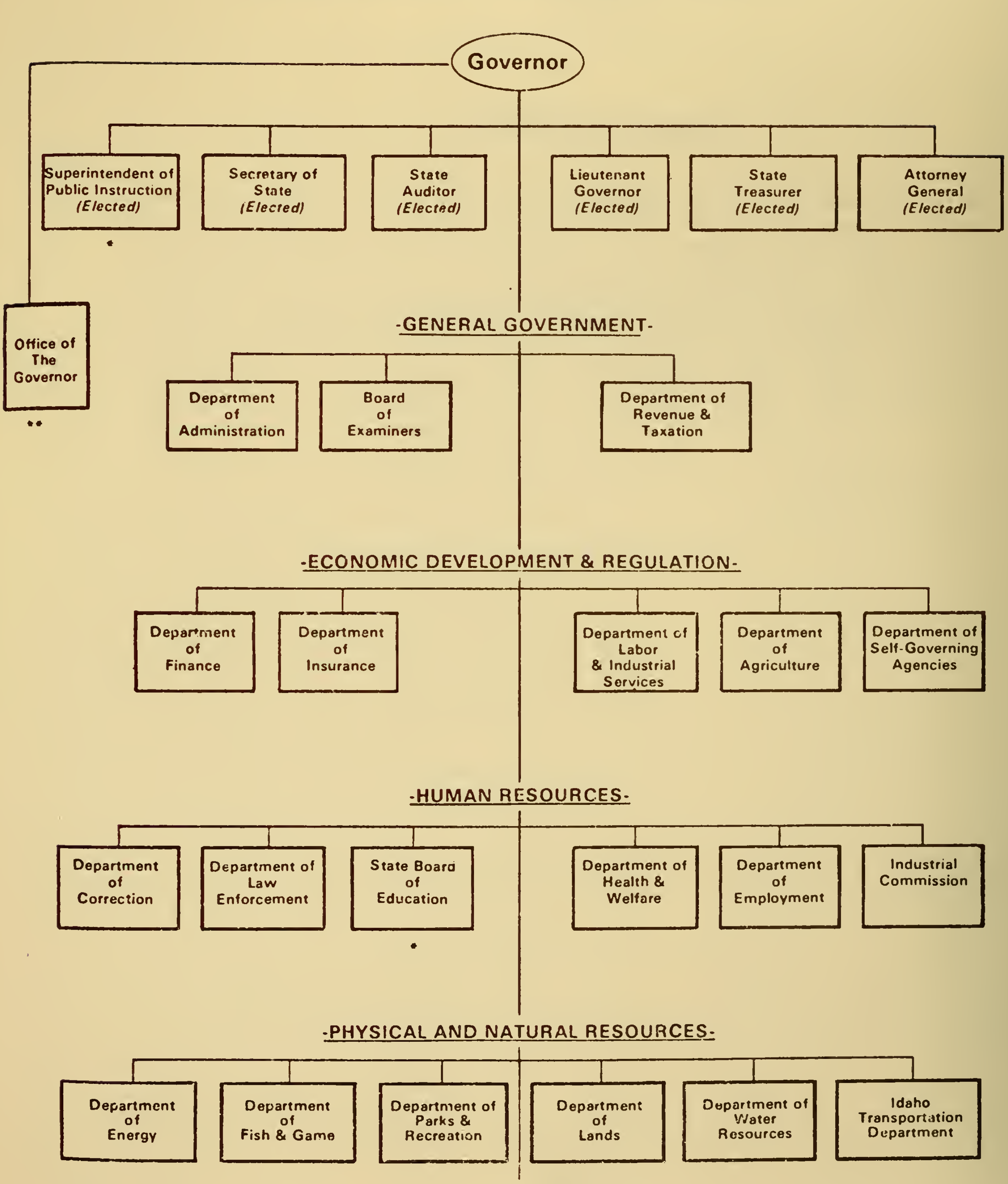
BILLING CODE 3125-01-M

b. State Flow Charts

NATURAL RESOURCES

Arizona Copper Tariff Board
Arizona Game and Fish Commission
State Land Department
Department of Mineral Resources
Oil and Gas Conservation Commission
Arizona Outdoor Recreation Coordinating Commission
Arizona State Parks Board
Arizona Solar Energy Research Commission
Arizona Water Commission

STATE OF IDAHO — EXECUTIVE BRANCH

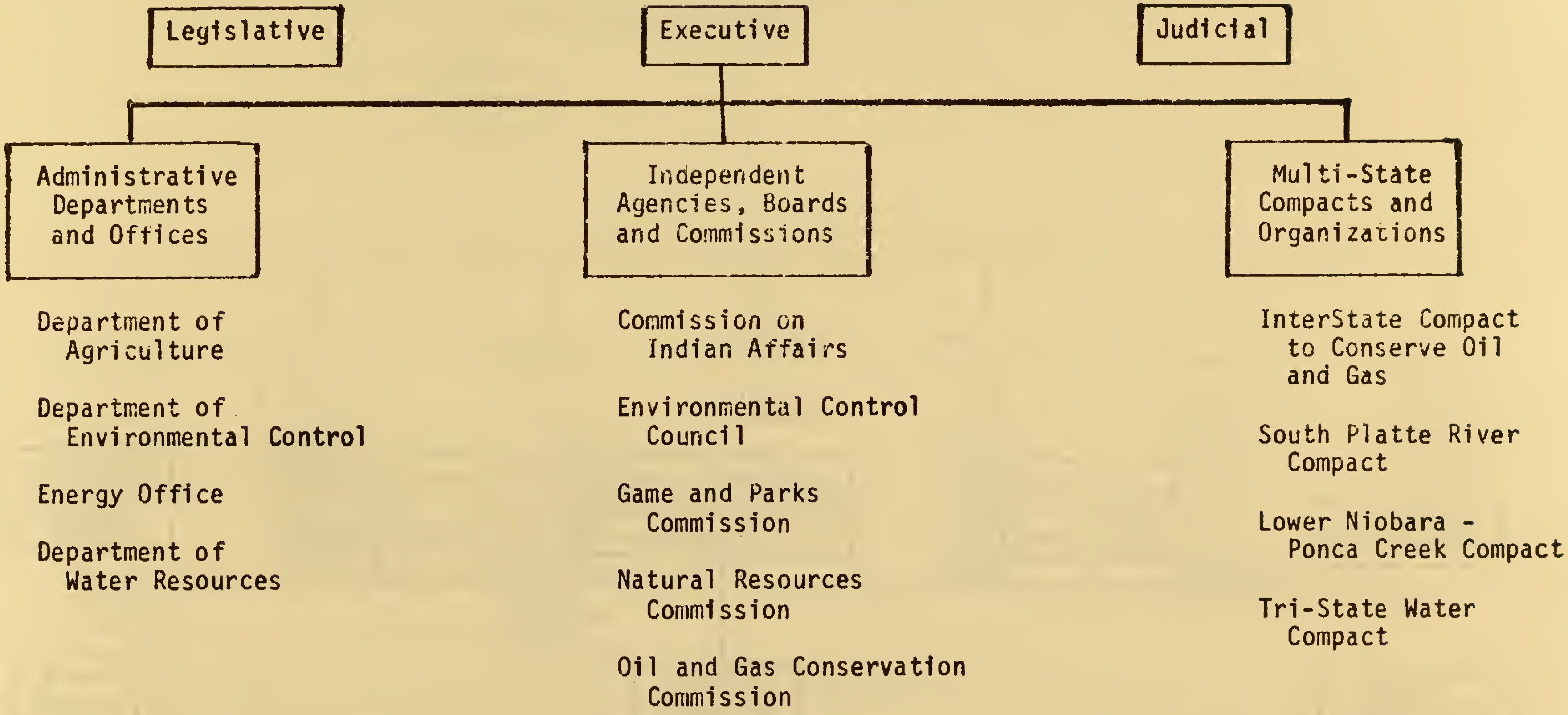

Governor
Superintendent of Public Instruction (Elected) *
Secretary of State (Elected)
State Auditor (Elected)
Lieutenant Governor (Elected)
State Treasurer (Elected)
Attorney General (Elected)
Office of The Governor **
-GENERAL GOVERNMENT-
Department of Administration
Board of Examiners
Department of Revenue & Taxation
-ECONOMIC DEVELOPMENT & REGULATION-
Department of Finance
Department of Insurance
Department of Labor & Industrial Services
Department of Agriculture
Department of Self-Governing Agencies
-HUMAN RESOURCES-
Department of Correction
Department of Law Enforcement
State Board of Education *
Department of Health & Welfare
Department of Employment
Industrial Commission
-PHYSICAL AND NATURAL RESOURCES-
Department of Energy
Department of Fish & Game
Department of Parks & Recreation
Department of Lands
Department of Water Resources
Idaho Transportation Department

FOOT NOTES

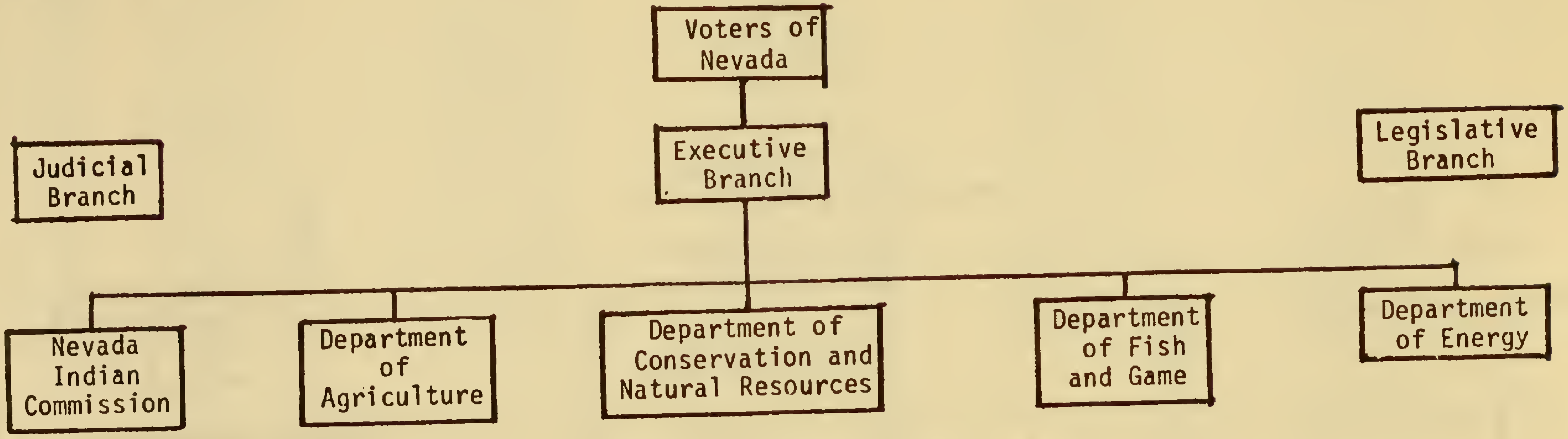
* *The Superintendent of Public Instruction is elected and serves as Director of the Department of Education and supervises elementary and secondary education functions.*

** *Contains the Division of Budget, Policy Planning and Coordination*

Nebraska Flow Chart - Selected Agencies

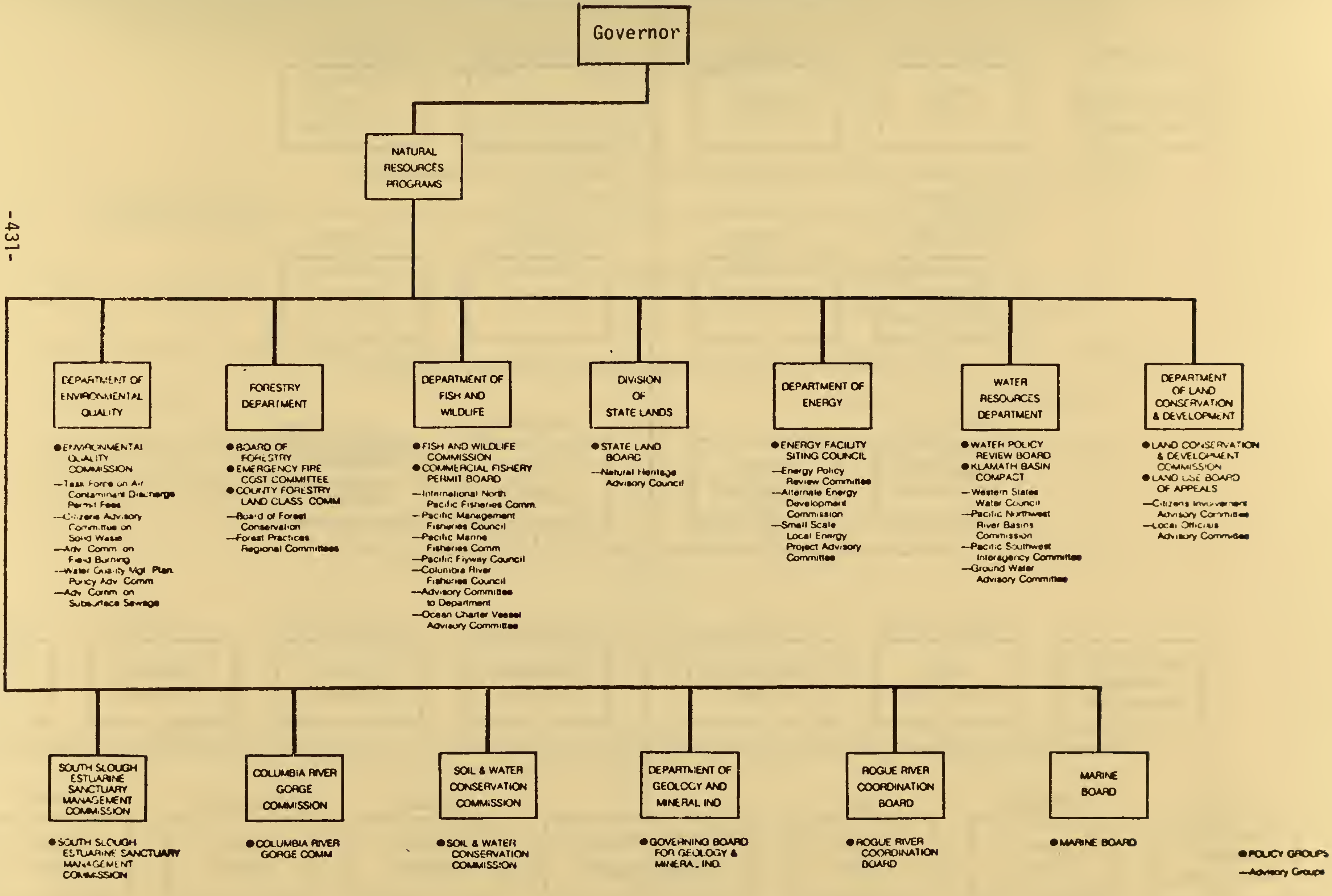

Legislative
Executive
Judicial
Administrative Departments and Offices
Independent Agencies, Boards and Commissions
Multi-State Compacts and Organizations
Department of Agriculture
Department of Environmental Control
Energy Office
Department of Water Resources
Commission on Indian Affairs
Environmental Control Council
Game and Parks Commission
Natural Resources Commission
Oil and Gas Conservation Commission
InterState Compact to Conserve Oil and Gas
South Platte River Compact
Lower Niobara - Ponca Creek Compact
Tri-State Water Compact

Nevada Flow Chart - Selected Agencies



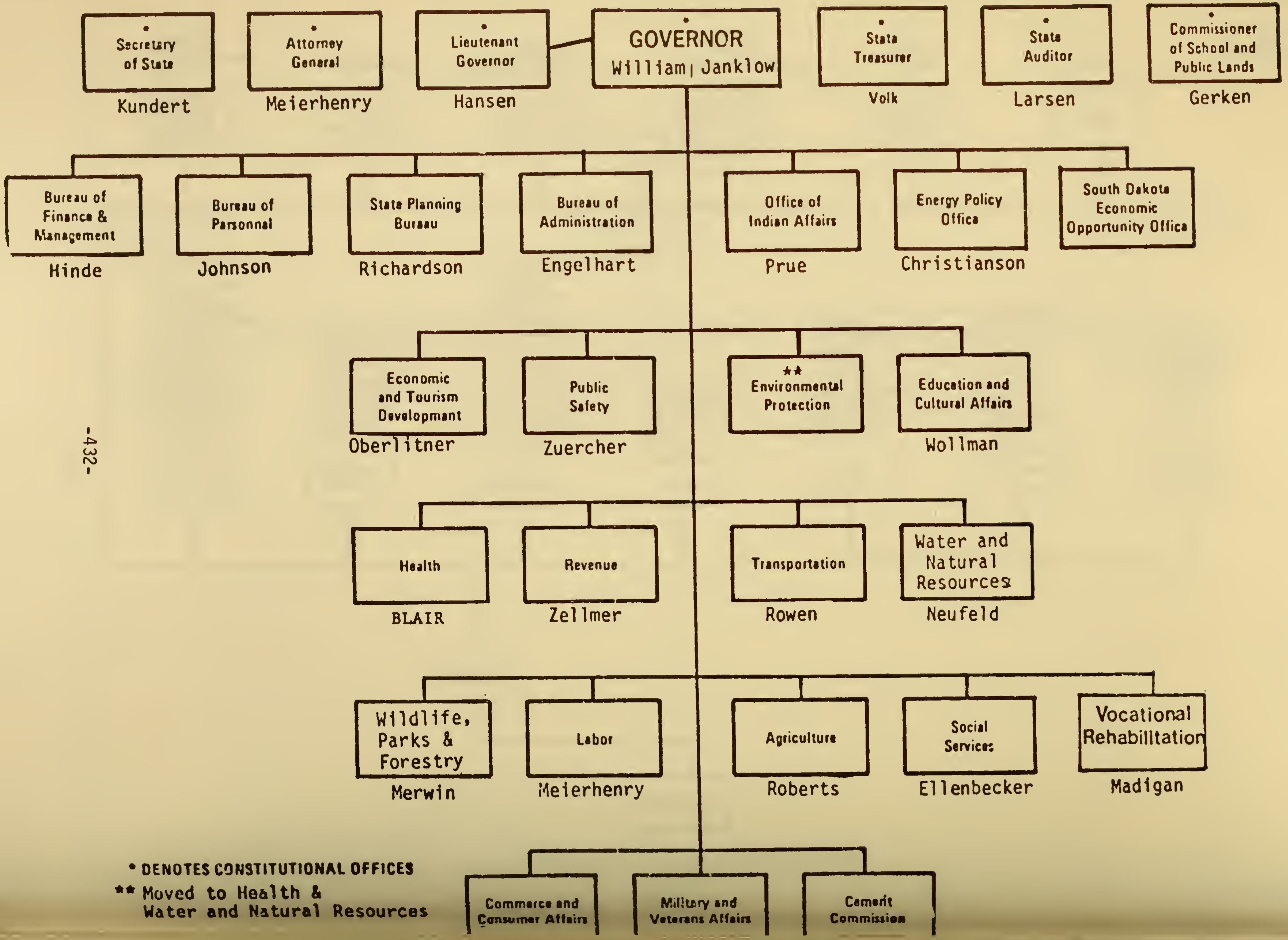
Oregon

NATURAL RESOURCES PROGRAMS


Governor
NATURAL RESOURCES PROGRAMS
DEPARTMENT OF ENVIRONMENTAL QUALITY
● ENVIRONMENTAL QUALITY COMMISSION
—Task Force on Air Contaminant Discharge Permit Fees
—Citizens Advisory Committee on Solid Waste
—Adv Comm on Field Burning
—Water Quality Mgt Plan Policy Adv Comm
—Adv Comm on Subsurface Sewage
FORESTRY DEPARTMENT
● BOARD OF FORESTRY
● EMERGENCY FIRE COST COMMITTEE
● COUNTY FORESTRY LAND CLASS COMM
—Board of Forest Conservation
—Forest Practices Regional Committees
DEPARTMENT OF FISH AND WILDLIFE
● FISH AND WILDLIFE COMMISSION
● COMMERCIAL FISHERY PERMIT BOARD
—International North Pacific Fisheries Comm.
—Pacific Management Fisheries Council
—Pacific Marine Fisheries Comm
—Pacific Flyway Council
—Columbia River Fisheries Council
—Advisory Committee to Department
—Ocean Charter Vessel Advisory Committee
DIVISION OF STATE LANDS
● STATE LAND BOARD
—Natural Heritage Advisory Council
DEPARTMENT OF ENERGY
● ENERGY FACILITY SITING COUNCIL
—Energy Policy Review Committee
—Alternate Energy Development Commission
—Small Scale Local Energy Project Advisory Committee
WATER RESOURCES DEPARTMENT
● WATER POLICY REVIEW BOARD
● KLAMATH BASIN COMPACT
—Western States Water Council
—Pacific Northwest River Basins Commission
—Pacific Southwest Interagency Committee
—Ground Water Advisory Committee
DEPARTMENT OF LAND CONSERVATION & DEVELOPMENT
● LAND CONSERVATION & DEVELOPMENT COMMISSION
● LAND USE BOARD OF APPEALS
—Citizens Involvement Advisory Committee
—Local Officials Advisory Committee
SOUTH SLOUGH ESTUARINE SANCTUARY MANAGEMENT COMMISSION
● SOUTH SLOUGH ESTUARINE SANCTUARY MANAGEMENT COMMISSION
COLUMBIA RIVER GORGE COMMISSION
● COLUMBIA RIVER GORGE COMM
SOIL & WATER CONSERVATION COMMISSION
● SOIL & WATER CONSERVATION COMMISSION
DEPARTMENT OF GEOLOGY AND MINERAL IND
● GOVERNING BOARD FOR GEOLOGY & MINERAL IND
ROGUE RIVER COORDINATION BOARD
● ROGUE RIVER COORDINATION BOARD
MARINE BOARD
● MARINE BOARD
● POLICY GROUPS
—Advisory Groups

11 79

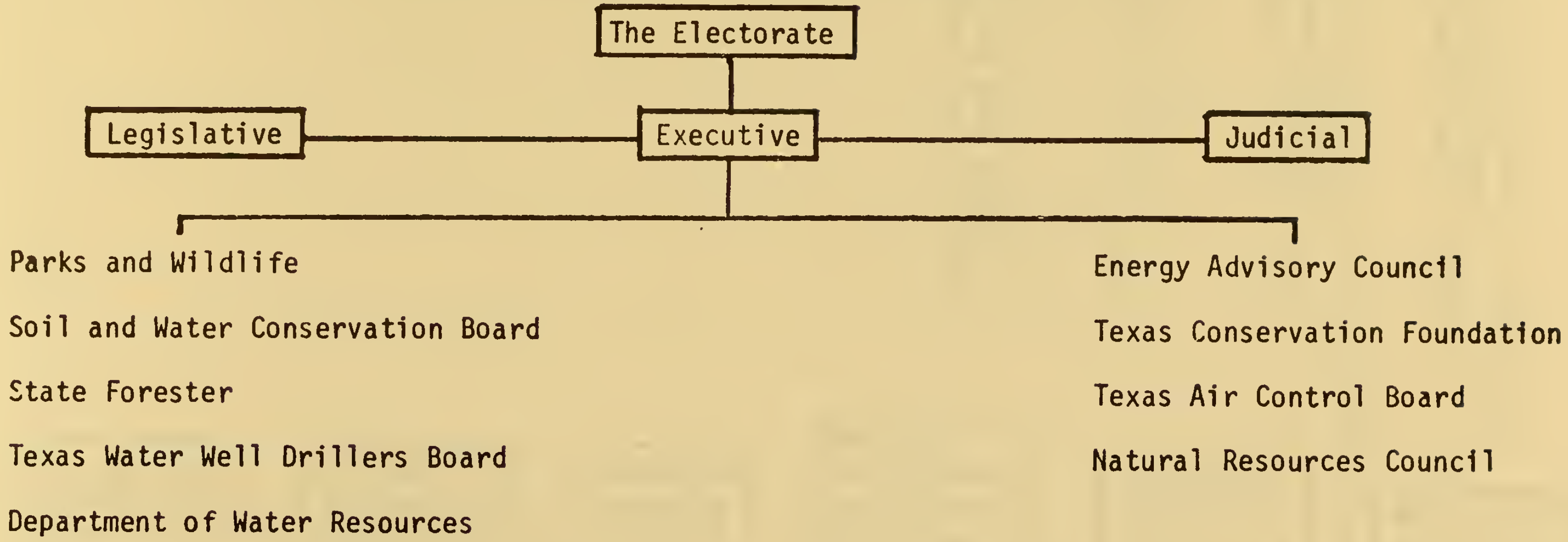
South Dakota



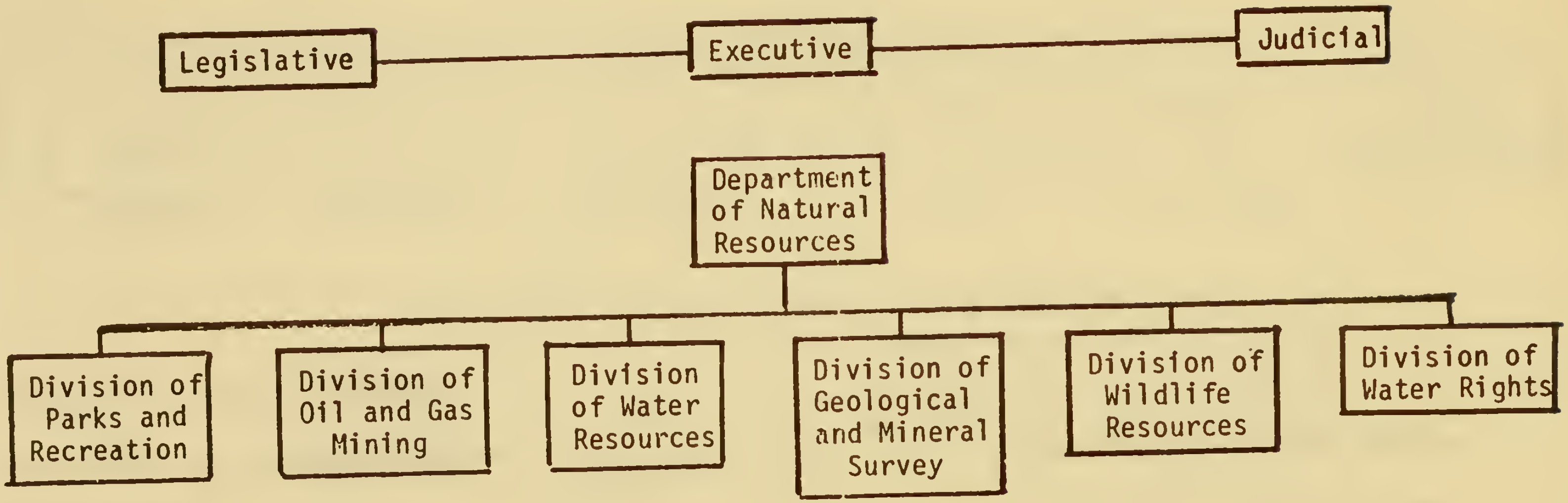
• DENOTES CONSTITUTIONAL OFFICES

** Moved to Health & Water and Natural Resources

Texas Flow Chart - Selected Agencies


The Electorate
Legislative
Executive
Judicial
Parks and Wildlife
Soil and Water Conservation Board
State Forester
Texas Water Well Drillers Board
Department of Water Resources
Energy Advisory Council
Texas Conservation Foundation
Texas Air Control Board
Natural Resources Council

Utah Flow Chart - Selected Agencies


Legislative
Executive
Judicial
Department of Natural Resources
Division of Parks and Recreation
Division of Oil and Gas Mining
Division of Water Resources
Division of Geological and Mineral Survey
Division of Wildlife Resources
Division of Water Rights

State Agencies involved in Natural Resource Planning
in the State of Wyoming

Wyoming Department of Agriculture
2219 Carey Avenue
Cheyenne, Wyoming 82002

Wyoming Department of Environmental Quality
Hathaway Building
Cheyenne, Wyoming 82002

Public Lands
Pioneer Building
Cheyenne, Wyoming 82002

Wyoming Forestry Division
22nd and Ames Street
Cheyenne, Wyoming 82002

Appendix M: Financial Support for Programs on Conservation and Management of Renewable Resources

Federal and state budgets are presented in this section. They provide an indication of the magnitude of spending associated with natural resources protection, conservation, and management. A further analysis of the budgets and their trends will be necessary to determine the support available for reassigning priorities to programs, implementing newer legislation, redirecting efforts, etc., if called for.

The Department of Agriculture, Department of the Interior, and the Environmental Protection Agency, which deal primarily with natural resources, have an FY 1981 combined budget estimate totaling in excess of $55 billion. Construction expenses, state and local spending, and other projects place the estimate much higher.

On the research side, the federal agencies spend about $250 million yearly in water resources-related research. In soil, water, and air research, USDA alone spent $43 million in 1979, while their total research and education budget for the same year was $708 million. Much of this research is conducted by state and private institutions.

In soil conservation practices, it has been estimated that the federal government spents over $500 million yearly. The state and local agencies' share has been estimated to be approximately $43 million. Amounts spent in conservation programs are included in this section.

a. Federal

UNITED STATES DEPARTMENT OF AGRICULTURE

Program Levels

(Dollars in Millions)

	FY 1979	FY 1980	FY 1981	Change 1980 to 1981
Agriculture and Nutrition:				
Farm Programs:				
Commodity Loans	$4,576	$4,244	$4,336	+$92
Commodity Payments	2,058	632	1,095	+463
Farm Loans (Excludes Emergency Loans)	1,732	1,855	1,849	-6
Disaster Relief	25	30	133	+103
Conservation Cost share ...	209	244	246	+2
Program Delivery	473	619	659	+40
Pest and Disease Control ..	239	255	261	+6
Production Research and Education	499	505	541	+36
Total, Farm Programs ..	9,811	8,384	9,120	+736
Marketing Programs	103	110	118	+8
Marketing Research and Education	59	59	58	-1
International Trade and Food Assistance:				
P.L. 480 Loans and Donations	1,374	1,604	1,615	+11
Export Credit	1,621	1,738	2,000	+262
Program Delivery	62	70	81	+11
Total, International Trade and Food Assistance	3,057	3,412	3,696	+284
Domestic Food and Nutrition Assistance	11,112	13,761	14,845	+1,084
Food Safety and Quality	328	347	356	+9
Food and Nutrition Research and Education	188	200	216	+16
Total, Agriculture and Nutrition	24,658	26,273	28,409	+2,136
Rural Community Development:				
Utility Loans	6,816	6,464	6,464	- -
Housing Loans	3,804	4,504	4,003	-501
Community Development Loans .	2,244	2,016	1,876	-140
Grants and Contracts	845	864	1,011	+147
Research and Education	98	101	102	+1
Program Delivery	677	668	922	+254
Total, Rural Community Development	14,484	14,617	14,378	-239
Natural Resources:				
Forest Resources	2,010	2,082	2,139	+57
Soil and Water Resources	496	515	525	+10
Research and Education	80	88	95	+7
Total, Natural Resources ..	2,586	2,685	2,759	+74
Management and Administration	66	74	80	+6
Total, USDA Program Level for Regular Programs	41,794	43,649	45,626	+1,977
Emergency Programs:				
Emergency Farm Credit	5,980	3,600	2,000	-1,600
Fighting Forest Fires	60	101	- -	-101
Grain Export Suspension Mitigation	--	2,000	800	-1,200
Total, Emergency Programs	6,040	5,701	2,800	-2,901
Total, USDA Program Levels ..	47,834	49,350	48,426	-924

Environmental Protection Agency

Summary of Resources
by Appropriation
(dollars in thousands)

Appropriation	1979 Budget Authority*		1980 Current Estimate		1981 Request		1981-1980 Difference	
	Workyears	$	Workyears	$	Workyears	$	Workyears	$
Salaries & Expenses	10,633	$452,989	10,940	$521,513	11,162	$562,542	+222	+41,029
Abatement, Control & Compliance	—	524,481	—	525,957	—	555,338	—	+29,381
Research & Development	—	221,403	—	234,574	—	264,984	—	+30,410
Scientific Activities Overseas	—	2,500	—	—	—	1,000	—	+1,000
Buildings & Facilities	—	1,172	—	1,425	—	4,115	—	+2,690
Reimbursements	65	—	64	—	64	—	—	—
U.S. Regulatory Council	—	—	11	3,082	11	3,338	—	+256
Subtotal	10,698	1,202,545	11,015	1,286,551	11,237	1,391,317	+222	+104,766
Construction Grants	—	4,200,000	—	3,400,000	—	3,700,000	—	+300,000
Subtotal	10,698	$5,402,545	11,015	$4,686,551	11,237	$5,091,317	+222	$+404,766
Oil and Hazardous Substances Liability Fund	—	—	—	—	—	250,000	—	+250,000
Grand Total	10,698	$5,402,545	11,015	$4,686,551	11,237	$5,341,317	+222	$+654,766

* Reflected for comparative purposes; 1979 appropriation structure differs in President's Budget Appendix.

BOD 1/22/80

Summary of Resources
by Media
(dollars in thousands)

Media	1979 Budget Authority* Workyears	1979 Budget Authority* $	1980 Current Estimate Workyears	1980 Current Estimate $	1981 Request Workyears	1981 Request $	1981-1980 Difference Workyears	1981-1980 Difference $
Air	1,927	$268,272	1,974	$250,490	1,887	$248,470	-87	-$2,020
Water Quality	3,123	332,280	3,088	337,435	3,033	335,088	-55	-2,347
Drinking Water	529	70,307	521	76,725	538	86,905	+17	+10,180
Solid Waste	292	73,878	406	100,060	774	147,448	+368	+47,388
Pesticides	1,001	68,234	987	68,156	914	74,000	-73	+5,844
Radiation	205	10,068	215	17,262	215	17,782	—	+520
Noise	98	10,893	105	13,075	99	12,927	-6	-148
Interdisciplinary	267	23,591	259	26,341	250	27,240	-9	+899
Toxic Substances	556	55,420	657	94,646	743	106,002	+86	+11,356
Energy	149	112,829	153	101,364	150	107,599	-3	+6,235
Management and Support	2,486	173,101	2,575	196,490	2,559	219,403	-16	+22,913
Reimbursements	65	—	64	—	64	—	—	—
Scientific Activities Overseas	—	2,500	—	—	—	1,000	—	+1,000
Buildings and Facilities	—	1,172	—	1,425	—	4,115	—	+2,690
U.S. Regulatory Council	—	—	11	3,082	11	3,338	—	+256
Subtotal	10,698	$1,202,545	11,015	$1,286,551	11,237	$1,391,317	+222	+$104,766
Construction Grants	—	4,200,000	—	3,400,000	—	3,700,000	—	+300,000
Subtotal	10,698	$5,402,545	11,015	$4,686,551	11,237	$5,091,317	+222	$+404,766
Oil and Hazardous Substances Liability Fund	—	—	—	—	—	250,000	—	+250,000
Grand Total	10,698	$5,402,545	11,015	$4,686,551	11,237	$5,341,317	+222	$+654,766

Reflected for comparative purposes; 1979 appropriation structure differs in President's Budget Appendix.

BOD 1/24/80

DEPARTMENT OF THE INTERIOR

Comparison of 1981 Estimate with the 1981 Base

(Dollar amounts in thousands)

	1981 Base		1931 Estimate		Inc.(+) Dec.(-)	
	Perm. Pos.	Amount	Perm. Pos.	Amount	Perm. Pos.	Amount
BUREAU OF LAND MANAGEMENT	6,214	885,052	6,318	997,495	+104	+112,443
(Annual Appropriation)	(5,863)	(519,452)	(5,967)	(566,200)	(+104)	(+46,748)
(Other Accounts)	(351)	(365,600)	(351)	(431,295)	(--)	(+65,695)
Management of Lands and Resources	4,704	314,989	4,808	357,550	+104	+42,561
Acquisition, Construction and Maintenance	166	16,793	166	16,750	--	-43
Payments in Lieu of Taxes	5	108,000	5	111,000	--	+3,000
Oregon and California Grant Lands	809	55,000	809	57,500	--	+2,500
Range Improvements	83	10,620	83	13,500	--	+2,880
Recreation Development and Operation of Recreation Facilities	3	300	3	300	--	--
Service Charges, Deposits and Forfeitures	93	13,750	93	9,600	--	-4,150
Permanent Appropriations	--	364,900	--	430,595	--	+65,695
Trust Funds	3	700	3	700	--	--
Miscellaneous Accounts	358	--	348	--	--	--
OFFICE OF WATER RESEARCH AND TECHNOLOGY						
Salaries and Expenses (Annual Appropriation) ...	83	30,913	83	38,513	--	+7,600
HERITAGE CONSERVATION AND RECREATION SERVICE	616	704,860	596	766,274	-20	+61,414
(Annual Appropriations)	(605)	(704,596)	(585)	(766,010)	(-20)	(+61,414)
(Other Accounts)	(11)	(264)	(11)	(264)	(--)	(--)
Salaries and Expenses	333	16,010	322	16,010	-11	--
Urban park and recreation fund	53	125,000	51	125,000	-2	--
Land and Water Conservation Fund	188	508,794	182	580,000	-6	+71,206
Historic Preservation Fund	31	54,792	30	45,000	-1	-9,792
Donations	--	264	--	264	--	--
Reimbursables	11	--	11	--	--	--
FISH AND WILDLIFE SERVICE	5,474	441,049	5,501	449,084	+27	+8,035
(Annual Appropriations)	(4,462)	(294,602)	(4,499)	(297,484)	(+37)	(+2,882)
(Other Accounts)	(1,012)	(146,447)	(1,002)	(151,600)	(-10)	(+5,153)
Resource Management	4,292	216,424	4,319	229,766	+37	+13,342
Construction and anadromous fish	170	59,078	170	47,968	--	-11,110
Migratory bird conservation account	155	29,900	155	26,500	--	-3,400
Development & Opera. of rec. facilities	--	200	67	250	--	+50
National Wildlife Refuge Fund	21	7,600	21	13,200	--	+5,600
Miscellaneous permanent appropriations	67	124,447	67	128,000	--	+3,553
Contributed funds	63	3,400	63	3,400	--	--
Other (trans. reim. etc.)	706	--	696	--	-10	--
NATIONAL PARK SERVICE	8,969	553,933	9,058	541,900	+89	-12,033
(Annual Appropriations)	(8,966)	(551,298)	(9,055)	(540,000)	(+89)	(-11,298)
(Other Accounts)	(3)	(2,635)	(3)	(1,900)	(--)	(-735)
Operation of the National Park System	8,297	401,155	8,386	427,697	+89	+26,542
Construction I	405	113,670	405	71,396	--	-42,274
Planning, dev. & opera. of rec. facilities	143	16,830	143	15,007	--	-1,823
John F. Kennedy Center for the Performing Arts ...	79	4,143	79	4,400	--	+257
Construction II	42	15,500	42	21,500	--	+6,000
Miscellaneous permanent appropriation	--	435	--	400	--	-35
Trust Funds	3	2,200	3	1,500	--	+700
GEOLOGICAL SURVEY	9,571	650,729	9,601	532,262	+30	-118,467
(Annual Appropriation)	(7,871)	(650,729)	(7,983)	532,262	(+112)	(-118,467)
(Other Accounts)	(1,700)	(--)	(1,618)	(--)	(-82)	(--)
Surveys, investigations, and research	7,859	475,028	7,971	485,761	+82	+10,733
Exploration of National Petroleum Reserve in Alaska	12	175,701	12	46,501	--	-129,200
Reimbursements	1,700	--	1,618	--	-82	--

(Dollar amounts in thousands)

	1981 Base		1981 Estimate		Inc. (+) Dec. (-)	
	Perm. Pos.	Amount	Perm. Pos.	Amount	Perm. Pos.	Amount
BUREAU OF MINES	2,672	138,260	2,672	158,966	--	+20,706
(Annual Appropriations)	(2,193)	(137,460)	(2,193)	(158,166)	(--)	(+20,706)
(Other Accounts)	(479)	(800)	(479)	(800)	(--)	(--)
Mines and minerals	2,193	137,460	2,193	141,538	--	+4,078
Contributed funds	10	800	10	800	--	--
Miscellaneous accounts	469	--	469	--	--	--
Helium Operations	--	--	--	16,628	--	+16,628
OFFICE OF SURFACE MINING RECLAMATION & ENFORCEMENT	1,025	181,508	1,036	187,831	+11	+6,323
Regulation and Technology (Annual Appropriation)	759	85,947	768	100,346	+9	+14,399
Abandoned Mine Reclamation Fund (Annual App.)	266	95,561	268	87,485	+2	-8,076
BUREAU OF INDIAN AFFAIRS	13,412	1,580,872	13,363	1,556,852	-49	-24,020
(Annual Appropriations)	(12,969)	(1,026,073)	(12,920)	(1,037,353)	(-49)	(+11,280)
(Other Accounts)	(443)	(554,799)	(443)	(519,499)	(--)	(-35,300)
Operation of Indian programs	12,476	808,765	12,427	823,290	-49	+14,525
Construction	123	93,783	123	93,638	--	-145
Road Construction	370	67,525	370	59,425	--	-8,100
Northwest Indian Fisheries (proposed)	--	--	--	5,000	--	+5,000
Alaska Native Claims	--	30,000	--	30,000	--	--
Permanent Appropriation	360	23,400	360	23,400	--	--
Miscellaneous trust funds	83	557,399	83	522,099	--	-35,300
OFFICE OF TERRITORIAL AFFAIRS	156	272,388	151	224,343	-5	-48,045
(Annual Appropriations)	(156)	(189,388)	(151)	(182,843)	(-5)	(- 6,545)
(Other Accounts)	(--)	(83,000)	(--)	(41,500)	(--)	(-41,500)
Administration of Territories	107	74,878	107	103,384	--	+28,506
Trust Territory of the Pacific Islands	60	114,510	55	79,459	-5	-35,051
Payments to the U.S. Territories, Fiscal Assistance	--	83,000	--	41,500	--	-41,500
OFFICE OF THE SOLICITOR						
Salaries and expenses (Annual Appropriations)	426	16,578	426	16,796	--	+218
OFFICE OF THE SECRETARY	1,350	55,288	1,395	58,637	+45	+3,349
(Annual Appropriations)	(980)	(55,288)	(1,025)	(58,637)	(+45)	(+3,349)
(Other Accounts)	(370)	(--)	(370)	(--)	(--)	(--)
Departmental Management	980	54,288	1,025	58,637	+45	+4,349
Salaries and Expenses (Special Foreign Currency Program)	--	1,000	--	--	--	-1,000
Other (Working Cap., reim., Youth Program)	370	--	370	--	--	--
TOTAL, DEPARTMENT OF THE INTERIOR funding for Bureaus in the Interior and Related Agencies Appropriations Act	49,968	5,511,430	50,200	5,528,953	+232	+17,523
(Annual Appropriations)	(45,599)	(4,357,885)	(45,923)	(4,382,095)	(+324)	(+24,210)
(Other Accounts)	(4,369)	(1,153,545)	(4,277)	(1,146,958)	(-92)	(-6,587)

Funds Appropriated by State and Local Governments for Conservation Programs, 1978

Region	Actual Appropriations ($000's)
Great Plains	$19,118
Mountain	$14,051
Pacific	9,599

Source: USDA, Agricultural Statistics, 1978

Agricultural Conservation Program - 1977

Region	Total Gross Assistance (000's)
Great Plains	$44,380
Mountain	$29,108
Pacific	$13,155

Source: USDA, Agricultural Statistics, 1978

Great Plains Conservation Program: Practices Applied and Cost-Shares Paid During 1956-77

Practice	Amount Applied 1956-77	Cost-Shares Paid 1956-77
Initial Application		
Establish permanent vegetative cover	2,617,341 acres	$23,655,730
Reestablish grasslands	2,122,262 do	$23,649,046
Terraces	87,405 miles	$24,105,509
Grassland mechanical treatment	380,768 acrea	$ 460,035
Reorganizing irrigation systems	9,191 systems	$ 7,966,636
Controlling competitive shrubs	5,708,035 acres	$15,964,049
Reapplication		
Establish permanent vegetative cover	178,810 acres	$ 1,514,312
Reestablishing grasslands	97,943 do	$ 1,046,588
Grassland mechanical treatment	220 acres	$ 220

Source: USDA, Agricultural Statistics, 1978.

Federal Expenditures for Irrigation and Water Conservation Works

(millions of dollars)

	Actual		Estimated	
	1971	1972	1973	1974
USDA: SCS (grants)	10.9	12.1	15.4	14.0
DOI: BIA	6.9	11.7	13.0	15.0
WPRS* (incl. grants and loans)	64.6	84.3	147.6	122.5

*The Water and Power Resources Service was formerly the Bureau of Reclamation.

Source: NWC, Water Policies for the Future, June 1973.

b. State

STATEMENT OF EXPENDITURES, REQUESTS AND RECOMMENDATIONS

GENERAL FUND	Actual 1978-1979	Estimated 1979-1980	Requested 1980-1981	Recommended 1980-1981
GENERAL GOVERNMENT	47,977,100	59,037,300	69,274,700	66,484,800
HEALTH AND WELFARE	152,666,100	173,851,600	211,928,600	199,020,000
INSPECTION AND REGULATION	21,323,500	24,928,600	30,215,000	26,507,700
EDUCATION	676,552,400	722,412,800	794,628,000	754,903,100
PROTECTION AND SAFETY	62,185,300	72,916,600	114,931,000	93,357,200
TRANSPORTATION	78,900	80,000	312,100	299,300
NATURAL RESOURCES	13,270,600	33,187,800	15,594,400	13,646,900
LAND, BUILDINGS AND IMPROVEMENTS	35,823,600	34,893,900	110,145,800	55,560,600
PROPERTY TAX REBATE	29,758,000	67,000,000		
SALARY INCREASES			52,300,000	34,800,000
	1,039,635,500	1,188,308,600	1,399,329,600	1,244,579,600
OTHER APPROPRIATED FUNDS				
GENERAL GOVERNMENT	6,383,500	6,773,600	8,597,000	7,820,000
HEALTH AND WELFARE	88,900	99,800	136,400	135,800
INSPECTION AND REGULATION	2,944,500	3,959,600	4,501,900	4,156,100
EDUCATION	62,810,900	82,702,400	87,707,500	89,834,600
PROTECTION AND SAFETY	22,683,000	26,869,100	24,752,000	24,752,000
TRANSPORTATION	76,292,200	86,428,100	96,590,800	93,512,400
NATURAL RESOURCES	8,543,800	8,080,300	10,052,100	9,915,600
LAND, BUILDINGS AND IMPROVEMENTS	2,384,600	2,888,600	18,608,800	17,983,300
HIGHWAY-AIRPORT CONSTRUCTION	43,940,300	61,284,000	45,280,000	45,280,000
PROPERTY TAX REBATE	26,843,300	28,000,000		
SALARY INCREASES			7,600,000	5,000,000
	252,915,000	307,085,500	303,826,500	298,389,800
OTHER FUNDS				
GENERAL GOVERNMENT	9,234,100	13,210,800	10,355,100	10,355,100
HEALTH AND WELFARE	176,509,500	190,363,200	213,131,800	213,131,800
INSPECTION AND REGULATION	1,162,700	1,313,200	1,434,300	1,452,300
EDUCATION	321,851,000	347,520,200	365,459,200	369,204,900
PROTECTION AND SAFETY	8,750,200	7,898,900	7,092,000	7,092,000
TRANSPORTATION	139,070,100	173,651,900	202,076,800	202,076,800
NATURAL RESOURCES	7,435,300	9,656,500	10,123,600	10,123,600
	664,012,900	743,614,700	809,672,800	813,436,500

Colorado

DEPARTMENT OF NATURAL RESOURCES

($ IN THOUSANDS)

The Department of Natural Resources is responsible for wide-ranging duties related to the State's land, water, mineral, recreation, and wildlife resources, as reflected by the existence of ten operating divisions within the Department.

Expenditure	Actual Expenditures 1978-79*	Estimate 1979-80	Governor's Budget 1980-81
Executive Director	$ 589	$ 1,454	$ 568
Administrative Services	853	927	958
Land Board	595	844	782
Water Conservation	2,084	1,084	1,132
Water Resources	5,516	5,155	5,266
Soil Conservation Board	314	251	258
Geological Survey	967	1,193	1,305
Mined Land Reclamation	375	804	870
Oil and Gas	428	448	469
Mines	659	861	873
Parks and Outdoor Recreation	4,779	4,973	5,139
Wildlife	18,367	20,296	22,894
TOTAL	$35,526	$38,290	$40,514
General Fund	10,276	10,966	10,330
Cash Funds	19,027	21,177	24,008
Federal Funds	6,223	6,147	6,176
FTE	1,084.9	1,143.8	1,179.8

* General Fund Actual Expenditures have been taken from the Financial Statement of the State Controller, October 15, 1979.

Executive Director - Harris Sherman
839-3311

Budget Director - Jim Corlett
839-3311

02 DEPARTMENT OF ENERGY

DEPARTMENT EXPENDITURE SUMMARY: Department of Energy

	FY 1979		FY 1980		FY 1981	CHANGE FROM
	APPRO-PRIATION	ACTUAL	APPRO-PRIATION	ESTIMATE	GOVERNOR'S BUDGET	FY 1980 APPRO.
By Program:						
0101 Management Services	$ 0	$ 0	$ 0	$ 0	$ 320,800	$ 320,800
0102 Energy Conservation	0	0	0	0	2,523,400	2,523,400
0103 Energy Resources	0	0	0	0	332,200	332,200
0104 Energy Policy and Research	0	0	0	0	110,800	110,800
0105 Public Affairs	0	0	0	0	139,000	139,000
0106 Fuel Services	0	0	0	0	182,600	182,600
TOTAL	$ 0	$ 0	$ 0	$ 0	$ 3,608,800	$ 3,608,800
By Source:						
1101 General	$ 0	$ 0	$ 0	$ 0	$ 900,800	$ 900,800
1392 Federal Energy	0	0	0	0	2,708,000	2,708,000
TOTAL	$ 0	$ 0	$ 0	$ 0	$ 3,608,800	$ 3,608,800
By Standard Class:						
Personnel Costs	$ 0	$ 0	$ 0	$ 0	$ 843,600	$ 843,600
Operating Expenditures	0	0	0	0	2,758,000	2,758,000
Capital Outlay	0	0	0	0	7,200	7,200
TOTAL	$ 0	$ 0	$ 0	$ 0	$ 3,608,800	$ 3,608,800
Total FTE Positions:	0.00	0.00	0.00	0.00	37.00	37.00

MAJOR PROGRAM EXPENDITURE SUMMARY: Administration

	FY 1979		FY 1980		FY 1981	CHANGE FROM
	APPROPRIATION	ACTUAL	APPROPRIATION	ESTIMATE	GOVERNOR'S BUDGET	FY 1980 APPRO.
By Minor Program:						
0101 Regional Offices	$ 478,200	$ 499,800	$ 477,100	$ 477,100	$ 569,600	$ 92,500
0102 Policy/Fiscal	526,400	256,000	510,500	510,500	538,800	28,300
TOTAL	$ 1,004,600	$ 755,800	$ 987,600	$ 987,600	$ 1,108,400	$ 120,800
By Source:						
2104 Inter-Accounts	$ 30,000	$ 0	$ 10,000	$ 10,000	$ 8,500	$ (1,500)
2206 Fish and Game Licenses (D)	973,300	717,600	975,600	975,600	1,092,400	116,800
2206 Fish and Game Licenses (F)	1,300	38,200	2,000	2,000	7,500	5,500
TOTAL	$ 1,004,600	$ 755,800	$ 987,600	$ 987,600	$ 1,108,400	$ 120,800
By Standard Class:						
Personnel Costs	$ 929,500	$ 847,500	$ 961,800	$ 961,800	$ 1,078,900	$ 117,100
Operating Expenditures	41,500	(118,900)	5,000	5,000	5,400	400
Capital Outlay	33,600	27,200	20,800	20,800	24,100	3,300
TOTAL	$ 1,004,600	$ 755,800	$ 987,500	$ 987,600	$ 1,108,400	$ 120,800
Total FTE Positions:	47.00	47.00	47.00	47.00	47.00	0.00

18 DEPARTMENT OF LANDS

DEPARTMENT EXPENDITURE SUMMARY: Department of Lands

	FY 1979		FY 1980		FY 1981	CHANGE FROM
	APPROPRIATION	ACTUAL	APPROPRIATION	ESTIMATE	GOVERNOR'S BUDGET	FY 1980 APPRO.
By Program:						
01 Supporting Services	$ 884,300	$ 831,500	$ 1,048,800	$ 1,048,800	$ 1,172,500	$ 123,700
02 Forest and Range Fire Protection	4,399,700	3,883,300	4,308,100	4,802,100	4,956,600	648,500
03 Forest Resources Management	3,376,900	3,334,700	3,372,100	4,190,600	3,790,700	418,600
04 Lands and Range Resources Management	890,300	701,400	818,500	818,500	872,500	54,000
05 Earth Resources Management	670,700	506,300	623,900	623,900	681,200	57,300
06 Maintenance, Gooding Tuberculosis Hospital	136,700	128,100	0	0	0	0
14 Soil and Water Conservation	486,200	624,200	503,400	653,400	679,700	176,300
15 Scaling Practices	113,800	78,300	117,700	134,900	147,200	29,500
TOTAL	$ 10,958,600	$ 10,087,800	$ 10,792,500	$ 12,272,200	$ 12,300,400	$ 1,507,900
By Source:						
1101 General	$ 4,674,700	$ 4,402,500	$ 4,788,000	$ 4,788,000	$ 5,170,400	$ 382,400
1105 Miscellaneous Receipts	17,800	10,000	40,300	40,300	68,700	28,400
1248 State Scaling	113,800	78,300	117,700	134,900	147,200	29,500
1254 Forest and Range Conservation	6,800	4,000	8,300	8,300	8,300	0
1255 Land Commissioner's Scaling Trust	293,000	254,700	420,200	420,200	479,600	59,400
1256 Forest Management	1,001,100	764,500	979,500	1,179,500	1,534,600	555,100
1277 U.S. Clarke-McNary	1,023,300	897,400	952,100	952,100	799,600	(152,500)
1281 Soil Erosion Control	275,500	146,100	282,400	282,400	292,200	9,800
1282 Insect and Disease Control	355,400	355,500	157,800	157,800	168,900	11,100
1283 Site Restoration	175,000	40,700	255,000	255,000	201,500	(53,500)
1284 Clearwater Potlatch Timber Protection Association	1,036,100	977,400	1,093,900	1,093,900	1,168,500	74,600
1285 Southern Idaho Timber Protection Association	74,000	71,000	77,700	127,700	137,700	60,000
1286 Ten Percent Grazing Lease	190,700	45,100	110,600	110,600	127,300	16,700
1237 Ten Percent Recreation Lease	19,100	7,500	32,900	32,900	35,500	2,600
1288 Ten Percent Timber Lease	1,340,500	1,128,000	1,250,800	1,345,800	1,518,500	267,700
1352 Pacific Northwest Regional Commission	0	50,600	0	0	3,400	3,400
1378 Land Federal	361,800	854,500	220,300	1,337,800	433,100	212,800
2253 Oil and Gas Commission	0	0	5,000	5,000	5,400	400
TOTAL	$ 10,958,600	$ 10,087,800	$ 10,792,500	$ 12,272,200	$ 12,300,400	$ 1,507,900
By Standard Class:						
Personnel Costs	$ 5,539,400	$ 5,105,500	$ 5,757,100	$ 6,016,500	$ 6,690,300	$ 933,200
Operating Expenditures	4,762,800	4,258,300	4,435,700	5,443,500	4,942,200	506,500
Capital Outlay	307,900	401,100	258,700	329,700	296,900	38,200
Trustee and Benefit Payments	348,500	322,900	341,000	482,500	371,000	30,000
TOTAL	$ 10,958,600	$ 10,087,800	$ 10,792,500	$ 12,272,200	$ 12,300,400	$ 1,507,900
Total FTE Positions:	236.45	236.45	232.70	232.75	235.25	2.55

19 DEPARTMENT OF WATER RESOURCES

DEPARTMENT EXPENDITURE SUMMARY: Department of Water Resources

	FY 1979 APPRO-PRIATION	FY 1979 ACTUAL	FY 1980 APPRO-PRIATION	FY 1980 ESTIMATE	FY 1981 GOVERNOR'S BUDGET	CHANGE FROM FY 1980 APPRO.
By Major Program:						
01 Management and Support Services	$ 477,500	$ 668,000	$ 500,500	$ 531,000	$ 548,200	$ 47,700
06 Regional Offices	924,500	815,400	801,400	855,900	1,148,800	347,400
07 Technical Services	761,300	712,300	757,600	825,800	819,200	61,600
08 Project Studies	347,700	953,200	351,100	646,500	325,800	(25,300)
09 Operations	349,000	541,500	375,800	517,200	847,600	471,800
10 Water Resource Board Studies	0	0	435,000	716,000	0	(435,000)
TOTAL	$ 2,860,000	$ 3,690,400	$ 3,221,400	$ 4,092,400	$ 3,689,600	$ 468,200
By Source:						
1101 General	$ 2,320,200	$ 2,219,300	$ 2,457,400	$ 2,833,200	$ 3,194,100	$ 736,700
1238 Water Administration	177,200	172,600	177,200	127,200	257,600	80,400
1239 Watermaster Account	200,000	87,100	101,800	106,400	101,300	(500)
1302 Federal Water Account PNRC	0	0	0	57,000	0	0
1312 Water Resource Planning	0	46,600	0	15,600	0	0
1313 Landsat - PNRC	0	29,900	0	71,500	1,500	1,500
1332 Corps of Engineers	128,100	59,700	0	20,900	0	0
1335 Geothermal Research	0	219,800	0	245,200	4,900	4,900
1337 Water Rights Information System	0	62,000	0	36,400	2,800	2,800
1338 Coop State River Basin	34,500	429,900	50,000	30,000	0	(50,000)
1343 Dam Safety Program	0	151,400	0	42,300	4,400	4,400
1345 Federal Land Development	0	10,000	0	0	0	0
1358 Environmental Protection	0	0	0	71,700	123,000	123,000
1381 Idaho Drought Committee	0	13,400	0	0	0	0
1383 Drought Emergency Program	0	188,700	0	0	0	0
9323 Water Resource Conservation and Development	0	0	435,000	435,000	0	(435,000)
TOTAL	$ 2,860,000	$ 3,690,400	$ 3,221,400	$ 4,092,400	$ 3,689,600	$ 468,200
By Standard Class:						
Personnel Costs	$ 1,965,700	$ 2,134,100	$ 1,946,200	$ 2,222,900	$ 2,488,700	$ 542,500
Operating Expenditures	513,400	676,800	926,100	1,339,600	708,400	(217,700)
Capital Outlay	79,800	583,700	37,100	82,900	130,500	93,400
Trustee and Benefit Payments	301,100	295,800	312,000	447,000	362,000	50,000
TOTAL	$ 2,860,000	$ 3,690,400	$ 3,221,400	$ 4,092,400	$ 3,689,600	$ 468,200
Total FTE Positions:	99.14	102.00	90.00	104.00	101.50	11.50

FUNCTION NO 5 NAME Conservation of Agriculture and Natural Resources

SUMMARY OF EXPENDITURE ESTIMATES

EXPLANATION	ESTIMATED FY 1980	AGENCY REQUEST FY 1981	GOVERNOR'S RECOMMENDATION FY 1981
EXPENDITURES BY ACTIVITY			
Central Office	$ 345,160	$ 372,964	$ 368,285
Control Division	578,399	583,645	560,466
Dairy Division	238,477	255,431	254,101
Marketing Division	353,077	386,529	372,898
Noxious Weeds Division	205,753	239,102	223,861
Seed Laboratory	115,239	120,134	119,564
Statistical Division	146,838	171,451	167,526
Water Resources Division	2,015,993	2,254,353	2,094,314
Weights and Measures Division	300,361	346,839	342,294
Entomology Division	411,081	448,482	438,637
Meat and Poultry Division	1,753,855	1,787,471	1,626,428
Pesticide Use	462,566	497,902	480,920
Grade A Milk Inspection	612,233	676,173	658,716
Grants to Rural Water Districts	1,305,049	1,000,000	-
Grain Commodity Program	418,159	488,386	467,886
National Dam Inspection	349,189	268,695	268,695
Total Expenditures	$9,611,429	$9,897,557	$8,444,591
EXPENDITURES BY OBJECT			
Salaries and Wages	$5,543,592	$5,887,832	$5,634,173
Contractual Services	2,566,163	2,825,236	2,652,765
Commodities	132,896	133,464	119,248
Capital Outlay	63,729	51,025	38,405
Subtotal - State Operations	$8,306,380	$8,897,557	$8,444,591
Federal and State Aid to Local Units of Government	1,305,049	1,000,000	-
Total Expenditures	$9,611,429	$9,897,557	$8,444,591
EXPENDITURES BY FUND			
State Operations:			
State General Fund:			
Central Office	$ 207,658	$ 372,923	$ 211,462
Dairy Division	193,477	205,431	204,101
Marketing Division	263,420	269,731	256,100
Noxious Weeds Division	205,753	239,102	223,861
Seed Laboratory	61,055	72,134	67,363
Statistical Division	121,838	145,451	141,526

Nebraska

	STATE AGENCY	AGENCY REQUEST 1980-81	AGENCY REQUEST 1981-82	GOVERNOR'S RECOMMEND. 1980-81	GOVERNOR'S ESTIMATE 1981-82
03	LEGISLATIVE COUNCIL	5,022,623	5,199,792	4,693,498	5,004,521
04	POLICY RESEARCH OFFICE	1,375,347	1,399,152	1,353,269	1,449,379
05	SUPREME COURT	8,026,205	8,585,595	7,564,419	8,104,872
06	DISTRICT COURT	4,691,638	4,997,565	4,545,937	4,900,000
07	GOVERNOR	254,764	264,659	256,152	270,748
08	LIEUTENANT GOVERNOR	59,318	60,336	57,683	59,787
09	SECRETARY OF STATE	924,708	948,594	902,070	962,609
10	AUDITOR OF PUBLIC ACCT	1,578,256	1,678,503	1,516,189	1,619,771
11	ATTORNEY GENERAL	1,184,062	1,245,171	1,195,782	1,275,859
12	STATE TREASURER	82,934,608	82,943,275	82,915,070	82,935,215
13	DEPT OF EDUCATION	151,027,255	156,791,806	150,990,111	156,763,521
14	PUBLIC SERVICE COMM	1,227,921	1,294,293	1,220,611	1,304,432
15	BOARD OF PARDONS	249,709	260,663	235,602	252,917
16	DEPT OF REVENUE	50,882,633	55,456,864	41,495,339	48,917,211
17	DEPT OF AERONAUTICS	12,120,000	12,223,244	12,119,773	12,960,157
18	DEPT OF AGRICULTURE	9,786,247	9,870,833	6,674,834	7,130,573
19	DEPT OF BANKING	1,311,053	1,402,827	1,309,709	1,401,309
20	DEPARTMENT OF HEALTH	15,842,714	16,534,005	15,686,853	16,750,761
21	STATE FIRE MARSHAL	1,173,889	1,225,948	1,140,555	1,210,030
22	DEPT OF INSURANCE	1,520,945	1,602,075	1,432,420	1,511,929
23	DEPARTMENT OF LABOR	29,109,428	30,126,629	28,797,653	29,813,321
24	DEPT OF MOTOR VEHICLES	7,302,290	11,287,158	7,150,653	7,674,912
25	DEPT OF INSTITUTIONS	69,400,491	73,578,675	68,701,849	73,142,555
26	DEPT OF PUBLIC WELFARE	245,107,200	277,927,336	237,030,331	254,100,339
27	DEPARTMENT OF ROADS	183,784,067	163,906,300	183,187,925	195,894,267
28	DEPT OF VETRNS AFFAIRS	422,466	425,696	424,542	452,960
29	DEPT OF WATER RESOURCE	1,272,255	1,290,832	1,295,000	1,365,050
31	MILITARY DEPARTMENT	5,494,546	5,739,235	4,226,363	4,461,376
32	BD OF EDUC LANDS&FUNDS	208,055	181,899	1,764,449	1,880,696
33	GAME & PARKS COMM	16,952,631	18,111,190	15,806,101	16,916,389
34	NEBR PUBLIC LIBR COMM	2,564,495	2,691,168	2,217,306	2,425,331
35	LIQUOR CONTROL COMM	864,826	915,276	779,635	834,204
36	STATE RACING COMM	369,007	349,232	369,007	394,830
37	WORKMENS COMP COURT	575,706	586,949	550,246	580,749
38	COMM STATUS OF WOMEN	228,508	231,870	161,466	174,134
39	NEBR BRAND COMMITTEE	1,869,764	1,984,702	1,869,498	2,000,364
40	MTR VEH INDUST LICENS	220,142	225,707	217,765	237,409
41	REAL ESTATE COMMISSION	475,163	487,860	475,163	508,424
43	STATE ATHLETIC COMM	45,026	43,656	35,143	37,693
44	BOARD OF NURSING	290,773	302,145	261,855	280,184
45	BOARD OF BARBER EXAM	49,389	52,800	49,796	53,185
46	DEPT OF CORR SERVICES	28,003,388	31,033,921	26,459,742	30,429,530
47	NEBR EDUC TV COMM	4,017,974	4,257,393	3,140,401	3,344,527
48	POST SEC EDUC COMM	848,955	825,236	883,631	963,613
49	BD OF TRUSTEES ST COLL	732,952	487,955	455,246	480,925
50	STATE COLLEGES	35,104,368	37,521,952	34,150,614	36,956,683
51	UNIVERSITY OF NEBRASKA				
52	STATE BD OF AGRIC	88,374	92,644	89,469	94,773
53	AGRICULTURE ACTIVITIES	13,068	13,813		
54	ST HISTORICAL SOCIETY	2,588,445	2,737,058	1,900,[illegible]	2,324,044
55	NATURAL RESOURCES COMM	6,987,316	7,960,362	7,120,381	7,354,497
57	NEBR OIL & GAS CONSERV	189,501	200,413	188,571	201,770
58	ST BD OF EXAM ENGG&ARCH	146,642	161,059	136,468	140,230
59	JOINT MERIT SYSTEM				

ALL FUNDS

	STATE AGENCY	AGENCY REQUEST 1980-81	AGENCY REQUEST 1981-82	GOVERNOR'S RECOMMEND. 1980-81	GOVERNOR'S ESTIMATE. 1981-82
60	AG PRODUCTS COMM	156,310	167,330	153,431	164,171
61	CRIME VICTIM'S REP BD	157,388	179,101	76,095	95,997
62	BD OF EXAM LAND SURVEY	10,785	10,880	8,723	9,333
63	NEBR ST BD PUBLIC ACC	135,097	144,318	133,460	142,902
64	STATE PATROL	14,820,484	15,854,852	15,131,151	16,190,332
65	DEPT OF ADM SERVICES	33,523,612	36,883,146	33,652,343	36,000,086
66	BD OF EXAM-ABSTRACTORS	16,050	16,400	16,050	16,050
67	EQUAL EMP OPPOR COMM	665,385	698,250	652,778	698,472
68	MEXICAN/AMERICAN COMM	218,859	213,944	190,813	212,603
69	NEBR ARTS COUNCIL	971,830	1,132,030	876,689	919,893
71	ADVISORY COMM ON AGING	8,557,989	9,320,552	7,532,444	8,312,562
72	ECONOMIC DEVELOPMENT	2,688,442	2,756,206	2,625,751	2,801,785
73	LANDSCAPE ARCHITECTS	2,500	2,500	2,500	2,500
75	INVESTMENTS COUNCIL	202,244	211,846	204,080	218,365
76	BOARD OF PSYCHOLOGISTS	12,924	13,779	11,714	12,924
77	COM OF INDUST RELATION	187,041	201,406	162,487	171,424
78	NEB COMM ON LAW ENF	3,860,324	3,897,272	3,667,391	3,748,423
79	NEBR COMM ON DRUGS	557,685	575,093	549,492	562,353
80	STATE PERSONNEL OFFICE	1,091,871	1,035,094	1,067,881	1,142,632
82	COM FOR HEARING IMPAIR	160,465	170,700	110,000	160,500
83	COMM ON TECH COLLEGES	17,652,400		17,725,898	18,674,022
84	ENVIRONMENTAL CONTROL	4,413,923	4,575,157	4,196,924	4,350,710
85	EMPLOYEES RETIRE BOARD	6,928,455	6,939,838	6,930,918	6,952,288
86	STATE OFFICE PLANEPROG				
87	NE ACTABTY & DISCL COM	156,924	152,492	141,022	150,893
89	STATE CLAIMS BOARD	1,142,399	1,235,404	1,093,251	1,169,607
94	UNL	188,271,398	210,510,594		
95	UNMC	109,316,264	121,148,726		
96	UNO	42,564,008	47,289,843		
97	UNCA (CENTRAL ADMIN)	10,096,128	11,183,855		
51	UNIVERSITY-SYSTEMWIDE	150,247,798	390,133,018	125,911,364*	135,480,628*
	STATE TOTAL	1,445,060,290	1,511,239,029	1 190,064,979	1,267,229,861 .

ALL FUNDS

Nevada

BUDGET DIVISION
APPROPRIATIONS BY FUNCTION

	1979-80		1980-81	
	REQUEST	RECOMMENDS	REQUEST	RECOMMENDS
CONSERVATION AND NATURAL RESOURCES				
DEPT OF CONSERVATION				
DEPARTMENT OF CONSERVATION	397,295	290,349	399,009	293,199
FEDERAL LAND LAWS	9,060	9,060	9,060	9,060
TAHOE REGIONAL PLANNING	50,000	50,000	50,000	50,000
STATE ENVIRONMENTAL COMMISSION DIVISION	82,331	50,835	81,878	50,133
DIVISION OF MINERAL RESOURCES	64,452	55,049	113,902	78,839
DIVISION OF CONSERVATION DISTRICTS	101,483	54,226	111,732	55,735
DIVISION OF STATE LANDS	400,656	198,415	414,430	204,396
CAREY ACT TRUST FUND				
DIV OF WATER RESOURCES	1,103,220	901,570	1,113,944	923,937
CALIFORNIA NEVADA COMPACT COMM	3,000	3,000	3,000	3,000
DIVISION OF WATER PLANNING	143,717	103,901	148,373	107,047
DIVISION OF FORESTRY	1,511,373	988,717	1,353,636	981,233
FOREST FIRE SUPPRESSION	150,000	100,000	150,000	100,000
FORESTRY NURSERIES	166,184	72,108	136,292	69,768
FOREST & WATER SHED REHABILITATION	5,000		5,000	
ENVIRONMENTAL PROTECTION	614,660	540,491	619,631	570,278
DIVISION OF STATE PARKS	2,692,075	1,814,649	2,540,847	1,733,547
STATE PARK PLANNING & DEVELOPMENT	423,569	396,230	448,170	405,125
PARKS YCC PROGRAM	60,000		60,000	
VIRGINIA & TRUCKEE RAILROAD	23,113	20,019	17,110	15,800
DIVISION OF HISTORIC PRESERVATION & ARCHEOLOG	174,884	91,361	178,872	93,705
DEPARTMENT OF ENERGY	171,975	144,977	179,864	147,544
ENERGY-CONS & PLAN	43,950		44,637	
ENERGY RES & DEV	43,853	42,881	44,796	42,504
WESTERN INTERSTATE NUCLEAR COMPACT	15,000	15,000	15,000	15,000
STATE ENERGY RESOURCES ADVISORY BOARD	13,700	13,700	13,900	13,900
TOTAL DEPT OF CONSERVATION	8,464,550 $	5,956,538 $	8,253,073 $	5,963,750
DEPT OF F & G				
FISH AND GAME FUND	614,010	104,681	504,187	147,160
TOTAL DEPT OF F & G	614,010 $	104,681 $	504,187 $	147,160
TOTAL CONSERVATION AND NATURAL RESOURCES	9,078,560 $	6,061,219 $	8,757,260 $	6,110,910

STATE OF NORTH DAKOTA
EXECUTIVE OFFICE
BISMARCK

ARTHUR A. LINK
Governor

The Natural Resources Council 1979-81 biennium budget

Attorney General's Office	$2,973,299
Department of Agriculture	$1,645,849
Office of Energy Management	$12,750,542
State Forest Service	$1,146,215
Game and Fish Department	$8,276,818
Geological Survey	$2,736,581
State Health Department	$22,910,784
State Highway Department	$242,123,416
State Historical Society	$2,954,130
State Parks and Recreation	$13,307,764
Public Service Commission	$6,302,305
Soil Conservation Committee	$ 577,798
State Land Department	$ 828,675
State Planning	$2,145,936
State Water Commission	$5,929,285

Oregon

NATURAL RESOURCES
Agency Expenditures by Fund 1979-81

		Governor's Recommendation			*Legislative Action*		
	Statutory Authority	*General Fund*	*Other Funds*	*Federal Funds*	*General Fund*	*Other Funds*	*Federal Funds*
Columbia River Gorge Commission	Ch. 112	$ 6,447	$............	$ 23,361	$ 6,477	$............	$ 23,361
Emergency Fire Cost Committee							
Administrative Expenses	Ch. 16	....	17,800	....	....	17,800	....
Emergency Fire Suppression	Ch. 16	....	854,012	....	....	854,012(1)	....
Memo Total - Emergency Fire Cost Committee		....	(871,812)	....	....	(871,812)	....
Department of Energy							
Energy Facility Siting and Regulation	Ch. 290	....	653,360	....	....	678,360	....
All Other	Ch. 290, 726	....	1,137,690	1,084,256	....	1,684,383	8,956,426
Geothermal Heat - Klamath Falls	Ch. 290	....	....	....	50,000	....	....
County Emergency Planning	Ch. 726	....	....	....	....	200,000	....
Memo Total - Department of Energy		....	(1,791,050)	(1,084,256)	(50,000)	(2,562,743)	(8,956,425
Department of Environmental Quality							
Air Quality	Ch. 755	3,234,060	3,624,884	1,436,878	2,942,685	3,732,479	1,896,906
Noise Control	Ch. 755	462,772	....	36,477	289,101	14,343	105,831
Water Quality	Ch. 755	3,208,970	1,131,107	2,294,564	3,056,737	1,235,047	3,545,446
Solid Waste	Ch. 755	1,504,131	....	631,736	1,388,820	39,811	707,236
Agency Management	Ch. 755	1,650,406	1,508,037	53,908	1,422,450	1,633,664	53,980
Sewage Treatment Facilities Construction Loans	Ch. 755	....	18,500,000	....	....	15,000,000	....
Solid Waste Facilities Construction Loans	Ch. 755	....	6,500,000	....	....	5,377,000	....
Debt Service	....	4,700,910	14,094,842	....	4,700,910	14,094,842(1)	....
Memo Total - Department of Environmental Quality		(14,761,249)	(45,358,870)	(4,453,635)	(13,800,703)	(41,127,186)	(6,309,399
Department of Fish and Wildlife							
Fish Division	Ch. 461	6,198,357	9,102,418	12,769,825	6,976,847	9,102,418	13,085,943
Wildlife Division	Ch. 461	....	5,688,742	3,053,779	....	5,688,742	3,126,317
Administration and Support Services	Ch. 461	1,004,793	6,105,473	....	1,004,793	6,094,473	....

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(1) Estimate only. Not limited by statute.

	Statutory Authority	Governor's Recommendation			Legislative Action		
		General Fund	Other Funds	Federal Funds	General Fund	Other Funds	Federal Funds
Department of Fish and Wildlife-Continued							
Commercial Fishery Permit Board	Ch. 613	$.............	$.............	$.............	$ 65,400	$.............	$.............
Capital Improvement	Ch. 461	30,969	1,004,750	697,581	30,969	1,004,750	697,581
Capital Construction(1)	Ch. 461	....	500,000	1,370,000	....	500,000	1,120,000
Improvements for the Handicapped - Building Modifications	Ch. 759	....	....	....	....	13,892	....
Memo Total - Department of Fish and Wildlife		(7,234,119)	(22,401,383)	(17,891,185)	(8,078,009)	(22,404,275)	(18,029,841)
Forestry Department							
Protection from Fire	Ch. 462	4,374,270	15,111,759	1,504,567	4,022,825	16,592,809(1)	....
Protection from Insects and Disease	Ch. 462	541,351	....	....	487,625	....	....
Service Forestry	Ch. 462	1,833,847	187,074	1,005,697	1,608,507	187,074	1,273,661
Forest Practices	Ch. 462	1,685,162	1,123,442	....	1,553,850	1,035,898	....
State-Owned Forest Lands	Ch. 462	....	27,846,994	153,000	....	27,964,718(1)	....
Cooperative Fire Program	Ch. 462	....	1,631,372	....	....	1,631,372	....
Forest Patrol Fund - Eastern Oregon	Ch. 462	2,563,284	....	....	2,563,284	....	....
Forest Patrol Fund - Western Oregon	Ch. 462	....	....	....	71,967	....	....
Debt Service	Ch. 462	1,388,925	84,288	....	1,388,925	84,288(2)	....
Improvements for the Handicapped - Building Modifications	Ch. 759	....	....	....	....	60,701	....
Memo Total - Forestry Department		(12,386,839)	(45,984,929)	(2,663,264)	(11,696,983)	(47,556,860)	(1,273,661)
Department of Geology and Mineral Industries							
Comprehensive Geologic Investigation	Ch. 370	1,538,595	114,072	260,423	787,943	199,690	216,933
Mined Land Reclamation	Ch. 370	62,261	186,781	18,096	25,864	232,771	18,096
Administration and Support Services	Ch. 370	....	....	....	416,132	167,388	168,393
Memo Total - Department of Geology and Mineral Industries		(1,600,856)	(300,853)	(278,519)	(1,229,939)	(599,849)	(403,422)
Department of Land Conservation and Development							
Operating Expenses	Ch. 543	2,313,305	....	786,686	1,521,140	....	1,714,672

(1) Statutory limitation on Other and Federal Funds.
(2) Estimate only. Not limited by statute.

	Statutory Authority	Governor's Recommendation			Legislative Action		
		General Fund	Other Funds	Federal Funds	General Fund	Other Funds	Federal Funds
Department of Land Conservation and Development-Continued							
Land Use Planning, Maintenance, Update, and Coordination Grants	Ch. 543	$ 4,208,555	$.............	$ 1,450,000	$ 3,933,555	$.............	$ 1,928,776
South Slough Estuarine Sanctuary Land Acquisition and Management	Ch. 543	....	....	650,000	....	....	122,932
Memo Total - Department of Land Conservation and Development		(6,521,860)	....	(2,886,686)	(5,454,695)	....	(3,766,380)
Division of State Lands							
Natural Area Preserves Advisory Committee	Ch. 542	40,900	....	....	10,000	....	30,900
Common School Fund							
Management	Ch. 542	....	....	18,253	....	....	18,253
Rangeland Improvements	Ch. 542	....	196,216	....	....	196,216	....
Erroneous Sales	Ch. 542	....	....	....	....	24,000	....
Submersible Lands	Ch. 546	....	....	....	....	1	....
All Other	Ch. 542	....	1,987,405	....	....	1,934,877	....
South Slough Estuarine Sanctuary							
Management	Ch. 542	72,932	50,000	....	....	122,932	....
Land Acquisition	....	300,000	600,000	....	....	....	....
Memo Total - Division of State Lands		(413,832)	(2,833,621)	(18,253)	(10,000)	(2,278,026)	(49,153)
Marine Board							
Administration	Ch. 756	....	705,927	....	....	754,066	....
Boating Law Enforcement Contracts	Ch. 756	....	1,092,948	....	....	1,294,337	....
Boating Law Enforcement Capital Outlay	....	....	33,000	....	....	....	....
Marine Facility Grants	Ch. 756	....	1,900,000	....	750,000	....	....
Federal Funds	Ch. 756	....	....	....	....	....	47,036
Nonlimited	....	....	3,000	....	....	3,000(1)	....
Memo Total - Marine Board		....	(3,734,875)	....	(750,000)	(2,051,403)	(47,036)
Rogue River Coordination Board(2)	Ch. 121	439	....	....	439	....	....
Soil and Water Conservation Commission							
Administration	Ch. 178	292,048	....	....	287,398	....	....
Financial Aid to Soil and Water Conservation Districts	Ch. 178	54,050	....	....	54,050	....	....

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(1) Estimate only. Not limited by statute.
(2) Funds appropriated to the Executive Department.

	Statutory Authority	Governor's Recommendation			Legislative Action		
		General Fund	Other Funds	Federal Funds	General Fund	Other Funds	Federal Funds
Soil and Water Conservation Commission-Continued							
Federal Funds	Ch. 178	$.............	$.............	$ 67,604	$.............	$.............	$ 429,313
Memo Total - Soil and Water Conservation Commission		(346,098)	....	(67,604)	(341,448)	....	(429,313)
Water Resources Department							
Operating Expenses	Ch. 757	5,889,984	67,541	....	5,089,591	247,893	....
Water Bond Program Administration	Ch. 757	196,046	....	....	66,369	....	....
Water Development Project Loans	Ch. 757	....	50,000,000	....	....	50,000,000	....
Debt Service	Ch. 757	....	2,026,000	....	....	2,026,000	....
Federal Funds	Ch. 757	....	....	465,950	....	....	757,494
Memo Total - Water Resources Department		(6,086,030)	(52,093,541)	(465,950)	(5,155,960)	(52,273,893)	(757,494)
TOTAL - NATURAL RESOURCES		$ 49,357,769	$ 175,370,934	$ 29,832,713	$ 46,574,653	$ 171,726,047	$ 40,045,486

South Dakota - FY 1979

Department of Environmental Protection	$2,080,186
Department of Natural Resources	2,346,941
Department of Water and Natural Resources	3,494,014
Geological Survey	1,180,857

Texas

RECAPITULATION-ARTICLE III
EXECUTIVE AND ADMINISTRATIVE DEPARTMENTS AND AGENCIES

FISCAL YEAR 1981

	GENERAL REVENUE	OTHER FUNDS	TOTAL
Accountancy, Board of Public		$ 1,265,000	$ 1,265,000
Adjutant General's Department	3,813,514	425,000	4,238,514
Aeronautics Commission, Texas	4,001,185	348,313	4,349,498
Agriculture, Department of	13,922,431	400,000	14,322,431
Air Control Board	7,720,695	2,000,000	9,720,695
Alcoholic Beverage Commission		12,855,137	12,855,137
Amusement Machine Commission	586,832		586,832
Animal Health Commission	8,385,860	1,246,063	9,631,923
Architectural Examiners, Board of		238,026	238,026
Armory Board, Texas National Guard	1,476,129	4,997,349	6,473,478
Arts and Humanities, Texas Commission on the	1,492,808	483,192	1,976,000
Attorney General's Office	8,080,505	737,609	8,818,114
Banking, Department of		125,411	125,411
Barber Examiners, Board of		336,160	336,160
Battleship Texas Commission		280,937	280,937
Chiropractic Examiners, Board of		60,766	60,766
Coastal and Marine Council, Texas	212,924		212,924
Community Affairs, Department of	2,667,365	84,252,618	86,919,983
Comptroller of Public Accounts	45,948,293	15,881,219	61,829,512
Voter Registration	2,250,000		2,250,000
Miscellaneous Claims (H.B. 605) for Payment of Small Claims	500,000	1,000,000	1,500,000
County Taxes on University Lands	600,000		600,000
Confederate and Ranger Pensions	71,720		71,720
Control, Board of	15,364,673	1,991,336	17,356,009
Corrections, Department of	132,406,986		132,406,986
Cosmetology Commission	1,019,586		1,019,586
Dental Examiners, Board of		488,943	488,943

RECAPITULATION-ARTICLE III
EXECUTIVE AND ADMINISTRATIVE DEPARTMENTS AND AGENCIES

	FISCAL YEAR 1981		
	GENERAL REVENUE	OTHER FUNDS	TOTAL
Employees Retirement System	$ 255,141,434	$ 166,794,749	$ 421,936,183
State Pension Review Board	79,341		79,341
Employment Commission, Texas		93,970,743	93,970,743
State's Reimbursement to the Unemployment Compensation Benefit Account	2,000,000	2,500,000	4,500,000
Energy Advisory Council, Texas	834,946	83,000	917,946
Engineers, Board of Registration for Professional		610,182	610,182
Fire Protection Personnel Standards and Education, Commission on	110,449		110,449
Firemen's Pension Commissioner	251,641		251,641
Good Neighbor Commission	178,856		178,856
Governor, Office of the	2,420,887	339,895	2,760,782
Energy Office	264,445	8,280,180	8,544,625
Budget and Planning	2,743,712	1,075,000	3,818,712
Criminal Justice Planning		34,960,817	34,960,817
Committee on Aging	2,476,472	30,757,181	33,233,653
Film Commission	217,510		217,510
Payments for Contributions, Emergencies and Deficiencies	1,185,460	50,000	1,235,460
Governor's Commission on Physical Fitness	98,656		98,656
Hearing Aids, Board of Examiners in the Fitting and Dispensing of		42,449	42,449
Highways and Public Transportation, State Department of	17,700,000	1,332,496,500	1,350,196,500
Historical Commission, Texas	842,665	1,194,542	2,037,207
Housing Finance Authority, Texas	499,449		499,449
Indian Commission, Texas	460,188		460,188
Industrial Accident Board	4,000,039	294,403	4,294,442
Industrial Commission	1,485,353	780,451	2,265,804
Insurance, State Board of		13,784,214	13,784,214

RECAPITULATION-ARTICLE III
EXECUTIVE AND ADMINISTRATIVE DEPARTMENTS AND AGENCIES
(Continued)

	FISCAL YEAR 1981		
	GENERAL REVENUE	OTHER FUNDS	TOTAL
Intergovernmental Relations, Texas Advisory Commission on	263,517	$ 263,517	$ 527,034
Investigators and Private Security Agencies, Texas Board of Private	528,693		528,693
Irrigators, Texas Board of		27,500	27,500
Jail Standards, Commission on		240,315	240,315
Labor and Standards, Texas Department of	2,911,737	336,794	3,248,531
Land Office and Veterans' Land Board, General	5,210,042	1,250,000	6,460,042
Land Surveying, Board of		99,000	99,000
Landscape Architects, Board of		64,387	64,387
Law Enforcement Officer Standards and Education, Commission on		1,528,672	1,528,672
Library and Historical Commission	5,303,851	3,051,167	8,355,018
Medical Examiners, Board of		714,557	714,557
Morticians, Board of	188,586		188,586
Motor Vehicle Commission, Texas		181,681	181,681
Nimitz Memorial Naval Museum Commission, Fleet Admiral Chester W.	146,501	25,000	171,501
Nurse Examiners, Board of Vocational		396,025	396,025
Nursing Home Administrators, Board of	145,314		145,314
Optometry Board, Texas		80,427	80,427
Pardons and Paroles, Board of	9,707,474	445,573	10,153,047
Parks and Wildlife Department	11,702,858	56,749,704	68,452,562
Pest Control Board, Structural		298,138	298,138
Physical Therapy Examiners, Board of	58,365		58,365
Probation Commission, Adult	20,527,833		20,527,833
Psychologists, Board of Examiners of		90,791	90,791
Railroad Commission	3,059,587	13,106,106	16,165,693
Real Estate Commission		1,931,556	1,931,556
Safety, Department of Public	31,377,359	71,483,556	102,860,915
School Tax Assessment Practices Board	1,604,605		1,604,605
Secretary of State	4,389,753		4,389,753
Securities Board, State	1,549,844		1,549,844
Sesquicentennial Commission, Texas	100,000		100,000
Soil and Water Conservation Board	1,670,513		1,670,513

RECAPITULATION-ARTICLE III
EXECUTIVE AND ADMINISTRATIVE DEPARTMENTS AND AGENCIES
(Continued)

	FISCAL YEAR 1981		
	GENERAL REVENUE	OTHER FUNDS	TOTAL
State-Federal Relations, Office of	$ 595,740		$ 595,740
Tax Assessor Examiners, Board of		121,227	121,227
Tourist Development Agency	1,550,034		1,550,034
Treasury Department	1,938,099	7,636,744	9,574,843
Utility Commission of Texas, Public	3,134,469		3,134,469
Veterans Affairs Commission	1,278,458		1,278,458
Veterinary Medical Examiners, Board of		166,084	166,084
Water Resources, Department of	14,944,292	10,500,297	25,444,589
Water Well Drillers Board	9,000		9,000
TOTAL, EXECUTIVE AND ADMINISTRATIVE DEPARTMENTS AND AGENCIES	$ 667,409,533	$1,988,216,203	$2,655,625,736

No	Agency	1981-82 BIENNIUM REQUEST				GOVERNOR'S RECOMMENDATION			
		General Fund	Other Income	Federal Funds	Total	General Fund	Other Income	Federal Funds	Total
	RESOURCE AND RECREATION								
010	Agriculture Department	$ 7,919,818	$ 2,219,500	$ 102,500	$ 10,241,818	$ 6,409,932	$ 2,199,500	$ 102,500	$ [illegible]
029	Water Development Commission	1,272,158		120,000	1,392,158	817,097		120,000	[illegible]
037	State Engineer	4,672,264	126,540		4,798,804	4,430,575	116,919		[illegible]
038	Pari-Mutuel Commission		37,330		37,330		28,960		[illegible]
040	Game and Fish Department		29,260,968	3,479,999	32,740,967		29,260,968	3,479,999	[illegible]
042	Geological Survey	1,151,661			1,151,661	960,630			[illegible]
053	Economic Planning and Development	2,257,828		434,150	2,691,978	1,495,190		434,150	[illegible]
055	Oil and Gas Commission		1,605,583		1,605,583		1,492,721		[illegible]
060	Public Lands	3,183,369		359,575	3,542,944	2,565,332		359,575	[illegible]
066	Travel Commission	2,930,247			2,930,247	2,279,631			[illegible]
074	Recreation Commission	4,707,125	5,226,882	1,176,256	11,110,263	3,859,732	5,408,894	1,201,826	[illegible]
092	Hot Springs State Park	1,012,961			1,012,961	926,153			[illegible]
	TOTAL RESOURCE AND RECREATION	$ 29,107,431	$ 38,476,303	$ 5,672,480	$ 73,256,714	$ 23,744,282	$ 38,507,962	$ 5,698,050	$ [illegible]

GLOSSARY

and Abbreviations

Common Abbreviations *

acre	ac
acre-foot	af
acre-foot per year	af/yr
average	avg
billion gallons per day	bgd
capita	cap
cubic foot	ft^3
cubic feet per second	cfs
cubic meter	m^3
cubic yard	yd^3
dollars	dol.
foot	ft
gallon	gal
gallons per capita per day	gcd
gallons per minute	gpm
hectare	ha
inch	in
inches per year	in/yr
kilogram	kg
kilometer	km
kilowatt	kw
kilowatt-hour	kwh
liter	l
megawatt	mw
mile	mi

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*from SRM (Society of Rangeland Management) Glossary and Soil Science Society of America Glossary.

millimeter	mm
million	mil.
million acre-feet	maf
million acre-feet per year	maf/yr
million gallons per day	mgd
month	mo
number	no.
parts per million	ppm.
percent	%
square mile	sq mi
thousand	thou.
year	yr

Approximate Conversion Factors

1 hectare (ha) = 2.47 acres

1 square mile (sq mi) = 2.59 km^2 = 640 acres

1 million gallons per day (mgd) = 1.12 x 10^3 af/yr = 694 gpm

1 billion gallons per day (bgd) = 1550 cf = 3.785 million cubic meters/day

1 inch = 25.4 millimeters (mm)

1 mile = 1.61 kilometers (km)

1 acre-foot (af) = 4,356 cf = 325,851 gal = 1,233.5 cubic meters

1 cubic foot (ft^3) = 28.317 l = .028 m^3 = 7.48 gal = 62.4 lbs. of water

1 cubic yard (yd^3) = 0.765 m^3

1 U.S. gallon = 3.785 l.

1 pound = 0.453 kg.

1 metric ton = 1.1 ton

Glossary

- A -

Abandonment - An intentional relinquishment of a known right. Concurrence of relinquishment of possession, and intent not to resume it for beneficial use. Neither alone is sufficient.

Acre-foot - The quantity of water required to cover 1 acre to a depth of 1 foot.

Agricultural Land Classification -

Cropland - Land used primarily for the production of cultivated crops, close-growing crops, and fruit and nut crops.

Pastureland - Land used primarily for the production of domesticated forage plants for livestock.

Rangeland - Land on which the natural potential (climax) plant cover is principally native grasses, grasslike plants, forbs, and shrubs. It includes natural grasslands, savannahs, certain shrubs and forb lands, most deserts, tundra, alpine communities, coastal marshlands, and wet meadows. It also includes lands that are revegetated naturally or artificially and are managed like native vegetation. It is not cultivated, drained, irrigated, or mechanically harvested.

Albedo - The amount of solar radiation reflected by a surface.

Atmospheric albedo - The amount of radiation reflected by clouds and other particles in the atmosphere.

Surface albedo - The amount of radiation reflected by the surface of the earth.

Alkalinization - Process by which alkali salts accumulate in the soil.

Allotment - An area designated for the use of a prescribed number and kind of livestock under one plan of management. It generally consists of public lands but may include parcels of private or State-owned lands. The number of livestock and season of use are stipulated for each allotment. An allotment may consist of several pastures or only one pasture.

Alluvial - Related to sediment deposited by streams.

Alluvial soil - A type of soil that develops from waterborne sediment; azonal.

Animal unit - The range livestock measurement equivalent to one mature (1,000 lb.) cow or the equivalent based upon average daily forage consumption of 26 lbs. dry matter per day, usually one horse, five sheep, etc.

Animal unit month (AUM) - A measure of forage or feed required to maintain one animal unit for a period of 30 days.

Aquifer - A saturated underground body of rock or similar material capable of storing water and transmitting it to wells or springs.

Aquifer recharge - The process of refilling an aquifer from which water has been drawn.

Arid lands - Areas where annual evapotranspiration loss equals or exceeds annual precipitation; where a deficiency of water prevails; where precipitation varies widely in time and space. Most arid areas have warm or hot temperatures in at least one season with the diurnal (daily) temperature variance wide. Wind and abundant sunlight are a common characteristic to arid lands.

The classification of arid lands is semiarid, arid, or extremely arid. On the average, semiarid lands receive 10-25 inches of annual precipitation, arid lands 5-10 inches, and extremely arid lands less than 5 inches. The United States contains land in each of the three classifications.

- B -

Biomass - The total amount of living plants and animals above and below ground in a particular habitat or area.

Biota - The flora and fauna of a region.

Browse - As a verb, to consume, or feed on or eat (a plant); as a noun, the tender shoots, twigs, and leaves of trees and shrubs often used as food by cattle, deer, elk, and other animals.

Browse line - A well-defined height to which browse has been removed by animals.

Brush - Vegetation consisting primarily of bushes and shrubs usually undesirable for livestock or timber management. It may sometimes be of value for browse or for watershed protection.

- C -

Carrying capacity - The maximum stocking rate possible without inducing damage to vegetation or related resources. It may vary from year to year on the same area due to fluctuating forage production.

Center pivot - Irrigation system in which a radial arm supporting sprinkler heads rotates on large wheels around a central pivot which is usually over a well. The result is a circular irrigated field usually one section (640 acres) in size.

Channel - That part of a natural stream where water normally flows or a ditch excavated for the flow of water.

Channelization - The process by which a natural stream is converted into a ditch for the ostensible purpose of flood control.

Clearcutting - A method of cutting that removes the entire timber stand from the area cut.

Compaction - Process by which soil is packed tightly, losing porosity.

Conservation tillage - A form of noninversion tillage that retains a protective amount of residue mulch on the surface throughout the year. Some conservation tillage methods are: minimum tillage, no till, reduced tillage, stubble-mulch tillage, chisel planting, and till planting.

Consumptive Use (of water) - Withdrawing water from a supply which, because of absorption, transpiration, evaporation, or incorporation in a manufactured product, is not returned directly to a surface or ground water supply; hence, water is lost for immediate further use.

Non-consumptive use (of water) - The act or process of using water that does not reduce its volume; the utilization of water in the process of producing a product which results in no deterioration of quantity or quality or transformation of water; primarily involves instream flow.

Contour farming - Plowing, cultivating, and harvesting crops along the contour of the land rather than up and down the slope; an effective technique for controlling soil erosion.

Cost-benefit analysis - Comparison of the expected benefits of a project with the anticipated costs of that project.

Cover - The material covering the soil and providing protection from, or resistance to, the impact of raindrops and the energy of overland flow, and expressed in percent of the area covered. Composed of vegetation, litter, small rock, and large rocks. These may be lying on or within 20 feet of the ground surface.

Cover crop - A close-growing crop grown primarily for the purpose of protecting and improving soil between periods of regular crop production or between trees and vines in orchards and vineyards.

Cropland - See Agricultural Land Classifications.

- D -

Deferred grazing - The use of delay or discontinuance of livestock grazing on an area for an adequate period of time to provide for plant reproduction, establishment of new plants, or restoration of vigor of existing plants.

Deposition - The process by which soil particles are transported by wind and/or water and are deposited in a place other than that of origin.

Desert pavement - The stony surface of some deserts caused by excessive erosion of the thin topsoil by the occasional heavy rainfall or by wind erosion.

Desertification - The gradual and sustained destruction or reduction of the land's capacity for plant and animal production.

Diurnal - by day.

Drainage - Gradual outflow of water by means of surface or subsurface water movement.

Drainage basin - The land area from which water drains into a river. Also called "catchment area," "watershed," or "river basin."

Drought - The condition of moisture deficit sufficient to have a temporal adverse effect on vegetation, animals, and man over a sizable area (Warrick, 1975).

. . . A prolonged lack of precipitation less than average (Russell, 1970).

. . . A prolonged weather condition characterized by deficient moisture and increased evaporation.

. . . Climatic excursion involving a shortage of precipitation sufficient to adversely affect crop production or range productivity (Rosenberg, 1979).

- E -

Ecosystem - A community of organisms in relation to their environment including both the living and non-living constituents, and forming an interacting system inhabiting an identifiable space.

Environment - The surrounding conditions, influences, or forces that affect or modify an organism or an ecological community and influence its development or existence.

Ephemeral stream - A stream which flows only after rainfall or snowmelt; or which does not flow continuously.

Erosion - The process by which portions and particles of soil are broken away and transported to another location by agents such as wind or water.

Accelerated erosion - Erosion much more rapid than normal, primarily resulting from the influence of the activities of man and animals, or natural events such as fire that exposes the surface.

Geologic erosion - The normal or natural erosion caused by geologic processes acting over long geologic periods.

Gully erosion - The erosion process whereby water accumulates in narrow channels and, over short periods, removes the soil from the narrow area to considerable depths, ranging from 1 to 2 feet to as much as 75 to 100 feet.

Natural erosion - Wearing away of the earth's surface by water, ice, or other natural agents under natural environmental conditions of climate, vegetation, etc., undisturbed by man. Synonymous with geologic erosion.

Normal erosion - The gradual erosion of land used by man which does not greatly exceed natural erosion.

Rill erosion - An erosion process in which numerous small channels of only several inches in depth are formed.

Sheet erosion - The removal of a fairly uniform layer of soil from the land surface by runoff water.

Splash erosion - The spattering of small soil particles caused by the impact of raindrops on soils. The loosened and spattered particles may or may not be subsequently removed by surface runoff.

Erosion pavement - A layer of coarse fragments of gravel and stones on the surface of the ground, remaining after the removal of the fine particles by erosion.

Evapotranspiration - Loss of water from the soil both by evaporation and by transpiration (passage as vapor through membranes) by plants living thereon.

- F -

Forage - Vegetative material produced by plants and used as food by animals.

Forb - A small broadleaf plant; weed.

- G -

Grasses - Narrow-leaved plants often used as forage.

Tall grass - Species such as bluestem, Indian grass, and wheatgrass generally ranging in height from 3 to 8 feet.

Short grass - Species such as buffalo grass and grama, generally ranging from 0.5 to 2 feet in height.

Grazing capacity - (See Carrying capacity)

Grazing district - An administrative subdivision of the rangelands under jurisdiction of federal or state management.

Ground water mining - The condition when withdrawals are made from an aquifer at rates in excess of net recharge; sooner or later the underground supply will be exhausted or the water table will drop below economic pump lifts; overdraft.

Gully - A channel cut by concentrated runoff through which water commonly flows only during or immediately after heavy rains or during the melting of snow. A gully is deep enough to interfere with, and not to be obliterated by, normal tillage operations.

Gully reclamation - The "mending" of a gully by either physical methods (check dams of boulders or cement) or vegetational means (planting of rapidly growing shrubs on the slopes).

- H -

Hardpan - A hardened or cemented soil layer. The sandy, loamy, or clayey soil material is cemented by iron oxide, silica, calcium carbonate, or other substances. The hardness does not change appreciably with changes in moisture content, and pieces of the hard layer do not slake in water.

Horizon - The distinctive horizontal layers that are apparent in vertical soil cross-sections.

Humus - Accumulated decomposed debris of plant stems, leaves, and roots forming the organic material in soils.

Hydrologic cycle - The circulation of water from the sea, through the atmosphere, as precipitation to the land, and then (with many delays) back to the sea by overland and subterranean routes, or directly back into the atmosphere by evaporation and transpiration.

- I -

Impact - A change in the ecosystem resulting from or accelerated by human action.

Infiltration - The passage of water into the soil by moving through pores and interstices.

Instream use - Use of water which does not require withdrawal or diversion from its natural watercourse. For example, the use of water for navigation, waste disposal, recreation, and support of fish and wildlife.

Interbasin transfer - The physical transfer of water from one watershed to another. On a large scale, the transfer of large quantities of water from one major river to another.

Intermittent stream - One which flows only during the wet season but which dries up during the dry season.

Invader - A plant species that was absent or present in only very small amounts in the undisturbed portions of the original vegetation but will become established therein under conditions of disturbance or continued overuse.

Inventory - A listing of the resources (and location), natural and manmade, which characterize a land area. It is a static picture of the basic resource situation, describing the quantity and quality of such attributes of land as geology, vegetation, soil, and water resources. A resources inventory provides a data base which then can be periodically updated, and trends illustrated, by suitable monitoring techniques.

Irrigation water management - The use and management of irrigation water whereby the quantity of water used for each irrigation is determined by the water-holding capacity of the soil and the need of the crop. The water is applied at a rate and in such manner that the crop can use it efficiently and no significant erosion occurs.

- L -

Land capability classification - The quality of soil resources for agricultural use without permanent damage is commonly expressed in land capability classes and subclasses which show, in a general way, the suitability of soils for most kinds of field crops. Soils are grouped according to their limitations when they are used for field crops, the risk of damage when they are used, and the way they respond to treatment.

Capability classes, the broadest groups, are designated by Roman numerals I through VIII. The numerals indicate progressively greater limitations and narrower choices for practical use. The classes are defined as follows:

Class I soils have few limitations that restrict their use.
Class II soils have moderate limitations that reduce the choice of plants.
Class III soils have severe limitations that reduce the choice of plants.
Class IV soils have very severe limitations that reduce the choice of plants
Class V soils are not likely to erode but have other limitations, impractica
to remove, that limit their use.
Class VI soils have severe limitations that make them generally unsuitable
for cultivation.
Class VII soils have very severe limitations that make them unsuitable for
cultivation.
Class VIII soils and landforms have limitations that nearly preclude their
use for commercial crop production.

Capability subclasses are soil groups within one class; they are designated by adding a small letter, "e," "w," "s," or "c," to the class numeral, for example, IIe. The letter "e" shows that the main limitation is risk of erosion unless close-growing plant cover is maintained; "w" shows that water in or on the soil interferes with plant growth or cultivation (in some soils the wetness can be partly corrected by artificial drainage); "s" shows that the soil is limited mainly because it is shallow, droughty, or stony; and "c," used in only some parts of the United States, shows that the chief limitation is climate that is too cold or too dry.

Litter - The uppermost layer of organic debris composed of freshly fallen or slightly decomposed organic materials; includes all undecomposed dead organic matter lying or standing within 20 feet of the ground surface. Litter includes lichens and moss having less than 1/16 inch growing on litter.

- M -

Macroclimate - The climate of a large geographical area.

Management - The decision-making process in the presence of uncertainty, that involves the manipulation of one or more of the dependent and/or the controlling factors.

Mesic - Characterized by, relating to, or requiring, a moderate amoung of moisture.

Microclimate - The climate of a localized and specific area.

Minimum tillage - Limiting the number of cultural operations to those that are properly timed and essential to produce a crop and prevent soil damage.

Monitor - To scrutinize or check systematically with a view to collecting certain specified categories of data.

Monoculture - Raising crops of a single plant variety, cultivated as well as natural.

Multiple use - In the case of resources, development of a particular resource to serve two or more purposes simultaneously.

- N -

Natural resource - Any component of the natural environment, such as soil, water, rangeland, forest, wildlife, that man can use to promote his welfare. A natural resource can be renewable or non-renewable.

Nonpoint source - Refers to pollution discharge from numerous scattered sites throughout a given area, transported to surface and ground waters through diffuse routes.

- O -

Off-road vehicle (ORV) - Any motorized vehicle designed for or capable of cross-country travel on or immediately over land, water, sand, snow, ice, marsh, swampland, or other terrain.

Overgrazing - Consumption of vegetation by herbivores beyond the endurance of a plant to survive; continued overuse creating a deteriorated range.

- P -

Pastureland - See Agricultural Land Classification.

Pedogenic - Related to soil formation.

Perennial stream - A watercourse which flows constantly throughout the year.

Phreatophyte - A deep-rooted plant that obtains its water from the water table or the layer of soil just above it.

Point source - Refers to discharge of pollution from discernible, confined, and discrete conveyance areas.

Public land - land in federal ownership.

Public use - Includes but is not necessarily limited to the following: stockwatering, human consumption, range improvement, protection and management, agricultural irrigation of native plants, fish and wildlife, fire, recreation, flood control, erosion control; does not include mining claims, mill sites, desert land entries, and Carey Act entries.

- R -

Range condition - The present productivity on a range site as related to the potential natural plant community for that site. Range condition is expressed as excellent, good, fair, or poor, on the basis of how much the present plant community has departed from the potential.

Reclamation - Rendering land suitable for cultivation.

Rehabilitation - Restoration of partially or totally lost biological productive capability.

Relative humidity - The ratio of absolute humidity to the maximum possible density of water vapor in the air at the same temperature.

Retorting - Operation by which substances are extracted, distilled, or decomposed by heat.

Rill - A small, intermittent watercourse with steep sides, usually only a few inches deep and, hence, no obstacle to tillage operation.

Riparian habitat - Habitat related to or located along a watercourse.

Roil - To make muddy or cloudy by stirring up sediment.

Runoff - The portion of precipitation which is not absorbed by the soil and which flows into surface waters.

Salinization - The process by which evaporation of salty water leaves a salt accumulation in the soil, which renders the soil unsuitable for crop production.

Scour - To abrade and wear away terrace, diversion channels, or streambeds.

Sedge - Grasslike plant having solid rather than hollow stems.

Sediment - Soil or mineral material transported by water and deposited in streams or other bodies of water.

Seepage - Water which passes into the soil from under a reservoir or other water body.

Site-specific - Refers to phenomena which occur under certain conditions at a particular site, but which would not necessarily occur at another site.

Slash and burn agriculture - A method of agriculture practiced in forests in which the land is cleared by cutting and burning. It is then planted and harvested, and after it loses its productivity, it is allowed to return to forest to regain productivity while another plot of forest is cleared and utilized.

Soil deterioration - Loss of potential productive capacity of a soil that results from destructive processes accelerated by the activities of man, for example, through soil erosion and waterlogging.

Soil moisture zone - Depth of soil from which plant roots extract water.

Soil order - Ten orders are recognized. The properties used to differentiate among orders are those that reflect the kind and degree of soil-forming processes that have taken place. Each order is identified by a word ending in sol. An example is Mollisol.

Soil profile - A cross-sectional view of a particular soil type in which the characteristic layers or horizons are well represented.

Soil structure - The arrangement or grouping of the soil's primary particles into granules or aggregates; a soil with good structure has a spongy or crumbly quality with an abundance of pores through which water and oxygen can move.

Soil texture - The size of the individual soil particles; the four textural categories ranging from the smallest to the largest sized particles are clay, silt, sand, and gravel.

Standard Metropolitan Statistical Area (SMSA) - An integrated economic and social unit with a large population nucleus. Each SMSA includes the county in which the central city is located, and adjacent counties that are metropolitan in character and economically and socially integrated with the county of the central city.

Streamflow - The discharge in a surface stream course.

Strip cropping - An agricultural practice in which an open row crop (potatoes, corn, cotton) is alternated with a cover crop (alfalfa, clover) to minimize soil erosion.

Stubble-mulching - Leaving the stubble of crops or crop residue essentially in place on the land as a surface cover during fallow and the growing of a succeeding crop.

Subsidence - Process by which the soil level is lowered by overdraft of groundwater, oil, etc.

- T -

Terracing - A soil conservation technique in which steep slopes are converted into a series of broad-based "steps"; the velocity of runoff water is thus reduced and soil erosion is arrested.

Transpiration - The process in which plant tissues give off water vapor to the atmosphere.

Turbidity - The cloudy condition caused by suspended solids in a liquid.

- U -

Ungulates - Hoofed mammals such as horses, cattle, and deer.

Urban and built-up areas - Human settlement and built-up areas of more than 10 acres, including industrial sites, railroad yards, cemetaries, airports, golf courses, institutional and public administration sites, and similar areas.

- W -

Water depletion - Water consumed that is irrecoverable to the hydrologic cycle or system.

Waterlogging - A condition in which the water table rises to near the surface of the soil.

Watershed - The total area drained by a particular stream; may range from a few square miles to thousands of square miles.

Water table - The upper level of an underground water body.

Wildlife habitat - All elements of a wild animal's environment which the animal needs to normally and naturally complete its life cycle. These elements are usually described as food, cover, water and living space, but included here are all the conditions and items needed to satisfactorily produce the above four elements in the amounts, qualities, and juxtapositions which the animal requires to complete its life cycle.

Withdrawal - Water taken from a surface- or ground-water source for offstream use.

-X-

Xerophytic - The quality of plants which are structurally adapted for life and growth with a limited water supply.

-Y-

Yardang - A sharp-crested ridge carved by wind erosion.

List of Abbreviations Used

AAAS - American Association for the Advancement of Science
AID - Agency for International Development
ASCE - American Society of Civil Engineers

BuCensus - Bureau of the Census, Department of Commerce

BIA - Bureau of Indian Affairs, Department of the Interior

BLM - Bureau of Land Management, Department of the Interior

BuRec - Bureau of Reclamation, Department of the Interior

CEQ - Council on Environmental Quality
DAUS - Desertification Assessment in the United States
DOE - Department of Energy
DOD - Department of Defense
ERDA - Energy Research and Development Administration

EIS - Environmnetal Impact Statement

EPA - Environmental Protection Agency
FAO - Food and Agriculture Organization, United Nations
GSA - General Services Administration

ICASALS - International Center for Arid and Semi-Arid Land Studies

MAB - Man and the Biosphere (a program of the United Nations)

NAS - National Academy of Sciences

NOAA - National Oceanic and Atmospheric Administration, Dept. of Commerce

NSF - National Science Foundation

NTIS - National Technical Information System, Department of Commerce

OSTP - Office of Science and Technology Policy, Executive Office of the President
OWRT - Office of Water Research and Technology, Department of the Interior

RCA - Resources Conservation Act

RPA - Resources Planning Act

SEA - Science and Education Administration, Department of Agriculture

SCS - Soil Conservation Service, Department of Agriculture

UNESCO - United Nations Educational, Scientific, and Cultural Organization

UNEP - United Nations Environmental Program

USDA - United States Department of Agriculture

USDC - United States Department of Commerce
USDI - United States Department of the Interior
USGS - United States Geological Survey, Department of the Interior

WPRS - Water and Power Resources Service (formerly BuRec)

WRC - Water Resources Council

WESTPO - Western Governors' Policy Office

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Library
Bldg. 50, Denver Federal Center
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